THE SENSE OF TASTE

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THE SENSE OF TASTE

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To

L. S. H.

AND

F. K. P.

EDITORIAL INTRODUCTION

Few people, comparatively, however intelligent and generally thoughtful, have as yet stopped to consider the surpassing interest and the unique importance of Our Senses. Living gateways as the sense organs are between ourselves and our ever-changing surroundings, both spiritual and material, they constitute the channels not only of our *life-satisfaction,* but of all our immediate *knowledge* as well. If, then, in discussing them, biological imagination and breadth and depth go hand in hand with technical knowledge of the highest grade, the volumes comprised should be both human and scientific. And these volumes are so, and will be. It is because of such possibilities that a series like the present, authentic yet interesting and inexpensive, must appeal to the intelligent man or woman of to-day. As contributions to psychology and to education their value is certain to be great, as indeed is indicated by the list of their authors, whom it would be superfluous to praise or even to portray.

Small in number are the topics in all the wondrous range of the science of living things that are more alluring for their very mystery and romance than these same gateways by which we

may go out into "our world" and by which this same great world may come into us and, for the little span of life, lend us a feeling of home-dwelling.

Within the past decade there has been a general popular awakening from the former uninterested attitude toward these phenomena of the physical and mental processes by which we keep in touch with the things outside ourselves. A fair knowledge of the rudiments of biology, of physiology, and of psychology now has become part of the curriculum of our schools and colleges. And of these three sciences it is psychology which has entered so deeply into our everyday life—business life as well as personal—that at last no one can escape its influence. And no one wishes to, for psychology in a sense has become the intellectual handmaiden of all who think in terms of to-day, with to-day's amazing development of insight into the mortal meanings of our very selves, body always as well as soul. Our scientific realization of our true continuity with all things else goes on apace, and our personal relations to the boundless, perhaps Infinite, Cosmos of consciousness, life, and energy seem ever clearer. Thus, in a way, the sense organs give us personal anchorage in a Sea which else sometimes, from its very immensity and stress, would overwhelm us. Our range, although the broadest as yet vouchsafed to

life, is as it were but a mere line out into the complexity of the Actual. The first step to the appreciation of this complexity and its implications for the human mind is knowledge of the conditions of its acquirement,—of the sense organs and of the perplexing brain behind them.

Editorial duty or privilege fails to know much as yet of the detailed contents of these several volumes. But the editor does know not a little about the arrangers and expounders of the volumes' contents, and he knows that they are women and men of conspicuous sense—trustworthy in every sense. The books are the best of their kind and are in a class by themselves. They are the standard authority for ordinary use. These volumes when disposed as a red-backed set on one's library shelf will be a set of books to be proud of. And the high school boys and girls and their fathers evenings and on Sundays and their mothers at the club all alike will think of them as highly valued friends, both wise and agreeable, as pleasant to meet for an hour as the most welcome visitor well could be. No higher "authority" exists than that which these authors represent; and it would be hard to find those who could set forth "authority" more gracefully. Each knows that literary *enjoyment* usually goes hand in hand with that *wisdom* which extended is the director of Life itself.

Although the sense of taste is more strictly a "biological" sense than any of the other simple senses of man—that is, more particularly concerned with the underlying bodily life—it plays, nevertheless, a very important part in our personal psychology. Many of us find in tasting one of the fairly dependable satisfactions of our everyday living; and Satisfaction, it seems upon long reflection, comes pretty close to being the long-sought "highest good." The wholly needless and harmful bodily overweight of many of us attests how often this sense is made a malignant fetish to lure us evilward. Eve tasted—and in that alluring moment set an example too plain and too significant ever to be ignored. The sense of taste, none the less, is a wholly respectable and dignified mode of obtaining satisfaction.

And our respective "research magnificent" would *not* be quite so interesting, not so adventuresome, were our sense of taste, instead of a clear sense experience tingling always with some kind of satisfaction, were it, I say, only a subconscious instinct, part of the original organic nature of man, working in the dark of consciousness. And for a few of us, especially if we be chefs, or cooks, or tea-tasters, or dyspeptics, or epicures, or gluttons, or taste-perverts, and the like, taste is, perhaps, one of the most important of all mor-

tal experiences and of all scientific themes. And to the children how *much* it is!

Professor Hollingworth and his Columbia colleague, Doctor Poffenberger, have written a volume which seemingly would satisfy both the scientific reader and the general readers who from curiosity seek its information. The business man as well as his wife sitting beyond the living-room table will both find the something they hoped to find; and the keen school teacher and the all too infrequent schoolmaster will find part of that material for the development of intensive sense-training now obviously indispensable to the further evolution of our school system. For even taste, least intellectual of our senses, can be intensively and hence usefully trained and thus education be furthered.

The authors need no introduction to the educated million, but if they did, this book would furnish one which the most exclusive hardly could disdain. They are to be congratulated on the success with which they have put much that is at once interesting and scientific up to the hour into little space, with "war-time economy." The authors have covered their field well.

The editor takes this first opportunity to invite criticism of whatever trend, and to ask for suggestions, whether from sense-gluttons or from

philosophers, for the better conduct and the furtherance of this series and of that other series, on "The Life of the Child," which he is editing. As is true in a wholly different field of conquest, here, too, lies safety in numbers, and where there are many men there are many minds. As all authors at least will hasten to agree, not even an editor knows all that might be known.

G. V. N. D.

CAMBRIDGE, MASSACHUSETTS,
January, 1917.

PREFACE

THE sense of taste is in numerous ways the most paradoxical of all the senses. Although, as a source of sense impression, it can afford the keenest immediate feelings of pleasure and delight, the books on æsthetics and art have little or nothing to say about it. Skill in the compounding of tastes and flavors, or discrimination in their relish, brings the expert neither artistic recognition nor social eminence. Taste, it is constantly asserted, is one of the "lower senses," and neither in the enjoyment of it nor the ministration to it is there to be acquired the merit and general esteem that readily distinguish an art from a service.

Nevertheless we commonly use the word "taste" for the expression of just those qualities of fine discrimination and delicate perception which are most conspicuously the marks of æsthetic appreciation. In our choice of figures of speech we reserve "vision" for the impersonal and remote intuition of the seer and the philosopher. "Touch" we use to express such intimate and personal impressions as sympathy and pity.

"Sound" seems best to indicate, through "noise" or "tone," either the self-seeking clamor of aggression or the mere passive possession of a certain richness of quality. "Odor," in its most common figurative use, suggests the reprehensible and undesirable motive. "Warmth" and "chill" bespeak at once the depth of emotion or affection. But the special fineness of soul which shows itself in the active and judicious choice of the appropriate and the harmonious, the subtly fitting and the delicately adapted, seems best expressed by the name of one of the "lowest" and most "vulgar" of senses,—"taste." Whether the judgment be exercised in the choice of color harmony or musical composition, costume or personal ornament, architecture, monument, design or arrangement, poetry or passing jest, rug, menu, pastime or associates, it is the sense of taste which furnishes the apt name for the critical capacity.

Not only is it in the usages of language that taste is a paradoxical sense; it is at the same time one of the most ancient of the special senses and also one about which exact knowledge is most difficult to acquire. It seems to afford a multitude of varying and distinctive *nuances* of sensation, yet it can boast but a meager equipment of four fundamental sense qualities. It is a primitive and well-established sense in the evolution of man, and individuals might therefore be expected to re-

semble each other closely in their experience of it; yet the most trite of proverbs insists that "there is no accounting for tastes." Indeed, in some languages it is even impossible to find distinctive names for such common taste experiences as bitter or even salt and sour. A survey of the phenomena and laws of the sense of taste reveals, in fact, no end of curious and interesting situations.

Of particular interest are the recent demonstrations of the great importance of taste for the general well-being of the organism. With the development of civilized modes of living men cease to rely implicitly or entirely on the sense of taste in their discrimination between wholesome and deleterious foods. They substitute for taste the evidence of the commercial trade-mark, the label, and the pure-food guarantee. It might have been supposed that under such circumstances the sense of taste would deteriorate through loss of function. But recent studies show that sensations of taste do far more than serve as clues to the acceptance or rejection of food. Such sensations appear, in fact, to be the initial stimulus to the whole series of digestive and assimilative processes on which the well-being of the organism depends. In much the same way the dulling or perversion of the taste sensations is often seen to constitute an early warning of grave disorder in the system

as a whole, and their restoration to presage the return to normal health.

Developing as one of the earliest forms of sensitiveness, intimately associated with the vital processes of life and growth, affording manifold richness of pleasure and aversion, full of paradoxical surprises and puzzling problems, and figuratively expressing one of the rarest of human qualities, " the sense of taste " constitutes one of man's most interesting contacts with the outer world.

In the chapters which follow an attempt is made to portray this contact in a manner which is both clear and concrete, yet scientifically accurate and technically complete. There are first considered the actual experiences which the sense of taste affords, their character, their analysis into the elementary qualities, and the classification, relations, and manner of combination of these qualities. A consideration of the delicacy of the taste sense, the precision of taste discrimination, and their methods of measurement, is followed by a discussion of the time relations of taste sensations, and a description of various special characteristics and phenomena of normal and abnormal tastes.

At this point there is presented a detailed description and illustration of the mechanism and function of the organ of taste, its gross structure

and anatomy, its accessory apparatus, its more minute nervous basis and composition, and its evolution in the individual and in the lower animal forms. Chapters are given to the nature of the external stimulus which provokes taste sensations, to disorders of the taste sense, to the differences between individuals, and to the function of sensations of taste in the higher mental processes of imagination, association, memory, and emotion. Finally, an account of the function of taste in the life of the organism is followed by a consideration of the place of the sense of taste in æsthetics and art, and in the complex interplay of human thought and social communication.

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CHAPTER I

The Qualities of Taste

The Taste Manifold

The casual observer would probably feel that any attempt to enumerate and arrange in a logical scheme the infinitude of tastes and flavors would be an impossible task. To him it might seem that nearly everything in the world possessed its own peculiar taste. Such an observer would also be likely to think it impossible and thankless to attempt to reduce to their necessary limits the various kinds of substance of which this infinitude of things is made up. But the chemist would readily be able to show him that the infinitude of substances consisted, as a matter of fact, only of various forms and combinations of less than one hundred " elements," and that from these elements one could produce, by appropriate selection and apportionment, any one of the infinitude of substances.

Is it then possible, in the field of our sensa-

tions, to reduce to elemental categories or units the manifold * of concrete sense experience? In the case of visual sensations almost everybody knows that there are certain so-called " primary " colors, from which can be produced the whole range of color experiences known to man. Blue and yellow, red and green, these are the primary colors, and if to these, in their varying intensities, be added gray, with its range of brightnesses, we have the elementary components of all our visual experience. Such a distinctive color as that of fire clay, for example, may thus be said to contain, in specified degree and proportion, red, yellow, and gray, while the familiar color of a wild flower may contain, in specified relations, red, blue, and gray.

In a strict psychological sense, it remains true that each color experience is relatively unique and distinct. But it can readily be shown that these psychological fusions and compounds are elaborations of more unitary experiences which have as their basis distinct mechanisms in the nervous system and sense organs. For example, the sensation of " heat " is a readily recognizable and identifiable experience, yet the physiologist tells us that there is no separate sensory apparatus

* By a "manifold" is meant a great variety of objects or experiences organized into one system or constituting one field.

for this impression. Cold and warmth, we are told, depend on the stimulation of specific nerve endings. When these two types of endings, in the same general region of the skin, are simultaneously stimulated, as the result of the application of a stimulus with very high temperature, there arises that new experience of "hot," which is in this sense a combination of warmth and cold.

Is it similarly possible to reduce to elementary units the rich manifold of taste and flavor? If this can be done, in what way must such an analysis proceed? What principles of classification are revealed, and what and how numerous are the elementary taste qualities? The various attempts that have been made to analyze the taste manifold are as interesting as their results are instructive.

The Classification of Tastes

One method of classifying sense qualities that has often been advocated uses as its basis the varieties of objects, agencies, or stimuli * by the application of which the sense qualities are produced or aroused. Thus the whole field of sense experience might be divided into thermal, electrical, mechanical, photic (produced by light), etc. But such sensations as are aroused by electrical stimuli, for example, may be auditory,

* By a "stimulus," in this connection, is meant any object, force, or agent that acts upon a sense organ.

visual, cutaneous, gustatory (having to do with taste), etc., while these same varieties of sensory experiences may be aroused in some cases by mechanical stimulation. Hence the classification of stimuli does not yield an adequate analysis of modes of sensation. In the field of taste this method, although it has been seriously attempted, is equally futile. Thus various writers have attempted to group taste sensations according to the species of plants and animals whose tissues possessed sapid (taste-producing) qualities. It is obvious that this method is unsatisfactory, since it is by no means true that all specimens of a given vegetable taste alike. Even different parts of the same plant have widely different tastes, and indeed the taste of a given part varies widely with time and circumstances.

Even Chevreul, a famous early student of the sense of taste, adopted a chemical classification, on the basis of the composition of the substance tasted. Here again it is true that substances chemically very dissimilar may possess tastes which are strikingly alike. Thus acetate of lead, chloroform, and cane sugar, which, chemically considered, are very dissimilar, may easily be mistaken for each other if their taste alone is relied on; while starch, which is chemically closely related to sugar, has no taste. It is also true that such different tastes as sweet and bitter may char-

acterize substances which are chemically very closely related.

It is, however, true that certain broad lines of chemical classification may be drawn. Thus those substances belonging to the colloid * group are tasteless, the crystalloids all being sapid. When substances are arranged according to the "periodic law" of chemistry, the elements present in sweet-tasting substances are in general neither extremely positive nor extremely negative. While it is the general rule that soluble alkaloids are bitter, acids sour, sugars sweet, and salts salty, there are many curious exceptions in every case. "It is true that we get the taste of salt only from chemical salt; but there are chemical salts that taste sweet, others that taste bitter, others again that have no taste at all." Similarly, while it is true that sour tastes belong to acids, it is by no means true that all acids taste sour. Moreover, sugar of lead, which is a salt, tastes sweet; while sulphate of magnesia and other salts taste bitter.

Indeed, it is true that there are substances which have more than one taste, the taste varying with the region of the tongue at which the substance is applied. Thus saccharine, sulphate of magnesia, and acetate of potassium are said to have sweet or acid taste if applied to the side or tip of the tongue; whereas they are bitter if ap-

* Resembling jelly or glue, uncrystalline in character.

plied to the posterior part. There are various other substances which show similar changes in taste according to the point of their application. However such facts may be explained, it is clear that the classification of taste along chemical lines is not only beset with difficulties, but that even in attempting such classification we resort to the use of a more immediate classification, indicated by such words as sweet, sour, etc.

This resort to an immediately descriptive classification suggests that the various taste experiences, regardless of the stimulus provoking them, have certain similarities as direct experiences. This further suggests that a strict psychological classification, based on the attributes of tastes themselves, should be found through analysis. In the case of sensations in general, such a type of classification is the one that seems most satisfactory. Certain sense experiences, such as red, yellow, orange, seem, as a matter of immediate experience, to belong together and to be essentially different from such experiences as warmth, tickle, noise, dizziness, etc. Furthermore, it is found possible to pass by gradual steps of transition from red to yellow, through an intervening orange, while there exists no such intermediate region between red and tickle. As a matter of immediate experience, then, and regardless of the nature of the stimulus, or, so far as we

may be aware, of the part of the body stimulated, certain sense experiences seem to belong together, to constitute a certain *mode* of sensation, such as pressure, sound, etc.

Is it now possible to apply a similar test to the various *qualities* which comprise the *mode* or *sense* of taste, and thus arrive at an adequate classification and analysis of these qualities? The earliest attempts to analyze the tastes by this psychological method were often amusingly miscalculated. Thus Chatin, in 1880, presented a scheme in which the total manifold of taste was first divided into agreeable tastes and disagreeable tastes. The agreeable tastes were typified by those we call sweet, and the disagreeable by those we call bitter. It was, of course, at once necessary to indicate certain intermediate conditions in this scheme for a variety of tastes which were neither clearly agreeable nor markedly unpleasant. Moreover, it is a matter of common experience that a taste which is agreeable to one person (such as tobacco, olives, mustard) may be decidedly obnoxious to another person, or, indeed, even to the same person on a different occasion; so that such a classification cannot be said to represent in any fundamental way an analysis of tastes.

There have been a great variety of classifications proposed on this direct descriptive basis,

and a comparison of the various schemes at once suggests that the task is by no means as simple as it might seem. The number of elementary tastes ranges widely, some investigators enumerating five or six times as many fundamental taste qualities as others have recognized.

Haller enumerated twelve different qualities—stale, sweet, bitter, sour, sharp, tart, spicy, salt, urinous, putrid, spirituous, nauseating. It is evident that this classification represents only a transition step toward a psychological analysis and that it is by no means free from the suggestion of provoking substances (spirituous, putrid) and the suggestion of effects produced (nauseating).

Linnæus recognized somewhat fewer categories,—giving the following ten as fundamental, —sweet, spicy, oily, mucous, salt, styptic,* bitter, sour, aqueous, and dry.

Other authors have been content with indicating eight elementary tastes. Both Bain and Wundt have proposed a sixfold classification, as follows,—sweet, bitter, saline, alkaline, acid, and astringent or metallic. Most modern authorities reduce the number of elementary tastes to four, —sweet, salt, sour, bitter,—while at least three investigators have advocated a simple twofold classification, into sweet and bitter.

* Styptic,—causing contraction of tissus.

Taste Blends and Fusions

These divergent accounts of the elementary taste qualities are in large measure to be explained by the exceeding complexity of those experiences which we in everyday life refer to as "tastes." It was long ago shown that a classification of the various senses on the basis of the gross "sense organs" or parts of the body involved is as inadequate as one based on the nature of the stimulating agent. The eye as a gross sense organ yields experiences of pressure, pain, temperature, and strain, as well as experiences of color and brightness. But these varied sensations we recognize as belonging, as experiences, to quite distinct modes. Even more complex are the varied sense experiences which we may receive through stimulation of the tongue and the surrounding tissues. For the tongue as an organ yields not only sensations of pure taste quality, whatever these may be, but it also gives rise to experiences of pressure with the varying characteristics of smooth, rough, moist, dry, contact, tickle, etc.; to experiences of pain, with the ranging characteristics and intensities, such as sting, smart, prick, burn; to experiences of temperature, such as cold, warmth, heat; and to a vast complex of kinæsthetic or muscular experiences of contraction, torsion, strain, expansion.

In common experience these qualities of pressure, pain, temperature, and kinæsthesis are scarcely discriminated from the purely gustatory or taste qualities themselves. Thus we speak of "oily," "fatty," and "greasy" tastes, in which the "smoothness" is certainly identical with that felt by the fingers and other parts of the skin. Similarly the pungent, astringent, puckering, biting "tastes" may come from substances which have no taste at all in a strict sense, but which produce definite smarting or stinging sensations when applied to the surface of the skin or to exposed nerve endings (pepper, camphor). The puckering quality can be shown by the characteristic muscular reaction to be largely kinæsthetic and tactual in its origin. The difference in "taste" between cold ice cream and the same substance when melted indicates how much of the flavor is due to touch sensations and sensations of temperature. One observer, indeed, reports the experience of four different qualities of sensation from the stimulation of a single papilla,—a touch, a temperature, a taste, and a pain sensation.

Further, many substances, in addition to these locally aroused experiences of touch, temperature, pain, and movement, set up strong organic reactions in more or less remote regions as well as strong affective reactions: such as choking,

nausea, and vomiting, on the one hand, and extreme unpleasantness, disgust, distress, strain, and shock, on the other. In many cases these immediate reactions seem to be reflex or instinctive in their origin, and in other cases they seem to be conditioned reactions, based on past experiences and associations. Thus in one case the "taste" of ice cream, which was once agreeable enough, has come to be immediately nauseating in character.

In spite of all these facts many of the classifications of taste qualities have included the "oily," the "nauseous," the "astringent," etc., as primary taste experiences. Even if the complications we have thus far alluded to were the only ones concerned, it would be clear enough that the "tastes" and "flavors" of everyday conversation represent very complex fusions and compounds, and that an analysis of the true taste qualities, if such there be, must take these factors into account in some very careful experimental way.

But we have left until this point a single complicating factor which in itself is sufficiently serious to call for very careful technical procedure in the examination of the sense of taste. This is the fact that a very great number of our so-called tastes are not tastes at all, but really odors. The sense organ of smell is so situated that it may be

stimulated not only in the ordinary way, through particles borne into the nostrils by currents of air from the outside, but also by particles and vapors which pass up, from the mouth cavity, behind the soft palate, by way of passages called the "posterior nares."

In this way it happens that tasteless substances, with definite odor, are mistakenly supposed to have taste. In 1824 Chevreul reported a very simple experiment with which his name has since been universally associated. He pointed out that it is impossible to separate the action of a substance on the touch corpuscles of the tongue from its action on the taste buds themselves. He observed, however, that by a very simple expedient it is possible to eliminate to some degree the factor of odor. His classical experiment consisted in excluding the sense of smell in large part by pressing the nostrils with the fingers while the substance to be examined was presented to the tongue. In this manner he observed that a piece of camphor gum which had seemed to have a very distinctive taste had in reality no taste at all. When the nostrils were closed all that could be observed as the result of placing camphor on the tongue was a peculiar pricking sensation of touch, similar to that produced by various other substances. The sensation produced by the cam-

phor was thus not a taste at all, but a fusion of odor and touch.

If, under the simple conditions of Chevreul's experiment, the various substances be reduced to a state of like consistency, so that they cannot be recognized by the tactile sense, observers are usually much amazed to discover that through taste alone it is impossible to distinguish between quinine and coffee or between apple and onion. Many familiar experiences of daily life testify to the large contribution which the sense of smell makes to the supposed taste. How "tasteless" are our fruits, wines, cigars, and vegetables when one has a cold in the head, and the free passage of odorous particles to the organ of smell is obstructed! How often has the nasty taste of medicine been softened by Chevreul's simple technic of "holding the nose"! There are some cases in which the reverse of this situation occurs and volatile substances, entering the mouth through the nostrils, stimulate the taste buds in the upper and back part of the mouth. In such relatively rare cases the real taste is mistakenly interpreted as an odor. In this way chloroform seems to have the characteristic odor which is in all probability a sweet taste due to stimulation of the taste buds by the chloroform vapor.

Why should it be the rule that, since the taste and smell qualities are to be confused, smell

should so commonly sacrifice its claim, so that odors are called tastes rather than vice versa? No doubt this is true largely because of the customary presence of sensations of pressure, temperature, movement, and resistance which are localized in the mouth and in the organ of taste. These accompanying sensations suggest that the taste organs are active in determining the result, even when no true taste qualities are present. It is common for sensations to be displaced in some such way as this, just as the blind man, who is really getting sensations from stimuli in the palm of his hand, seems to be getting them at the end of his walking stick; or just as a faint sound may seem to come from any source to which we direct our attention. Similarly, the whole complex of touch, taste, and odor experienced as the result of "sniffing" at a particular substance are quite likely to be credited entirely to the sense of smell.

The Poverty of Taste

Here, then, is a most interesting situation, which has been described by the use of two apt phrases: "the poverty of taste" and "the self-sacrificing character of smell." Our analysis has tended constantly to rob the sense of taste of the richness which we ordinarily credit to it. In fact, modern authorities agree that there are only four qualities which can be truthfully classed as tastes,

namely, sweet, salt, sour, and bitter. What we took to be the taste manifold is really a meager equipment of four qualities, with such variations of intensity and combination as these may possess. Both the richness and the manifoldness come from qualities of other senses, parading under the guise of taste. Smell especially is prone to sacrifice its claim in favor of its neighbor, and it is common indeed for us even to use taste names in describing odors; we speak of "sweet odors" and "sour smells," although sweet and sour are primarily taste qualities. Smell, then, not only entirely yields many of its qualities to the various "taste blends," but allows some of its own sensations to pass under taste names.

Patrick has reported extended observations in which he studied the taste experiences of an anosmic,—a person who had lost the sense of smell. In some of his experiments this woman, with two other women as control subjects, after having been blindfolded, attempted to identify various substances taken into the mouth. The general principles on which the experiments were based are stated as follows: "In theory those substances not recognized by any of the observers depend for their recognition upon sensations of sight; those recognized by the normal observers but not by the anosmic depend upon sensations of smell for their recognition; while those recog-

nized by all observers depend upon either taste, touch, or muscle sensations." It was further suggested that those substances recognized by the anosmic but not by the normal subjects would seem to depend in the main upon touch or muscle sensations.

These experiments disclosed many curious and unexpected facts. Breads and meats, butter, cream, olive oil, and various fruits and vegetables could not be easily identified when only sight was excluded. One of the women, a housekeeper of long experience, could not recognize raw turnip, raw potato, boiled pumpkin, cranberry sauce, or fresh pear when she was blindfolded.

Chicken, turkey, and quail were found to differ surprisingly little in actual taste, especially if their characteristic texture, smoothness, and other tactual qualities were eliminated or disguised. The various values placed upon different meats, breads, etc., in the general esteem would seem to depend in great measure on associated ideas and emotions, rather than on their actual qualities for taste.

Especially interesting is the list of substances which were recognized and correctly named by both of the normal women in these experiments, but which the anosmic was unable to identify. Patrick enumerates twenty-seven such common substances. Among them, by way of example,

were vanilla extract, pineapple syrup, banana, grape, quince, strawberry, tea, chocolate, sour milk, kerosene, claret, rhubarb, onion, eggs, and boiled turnips. The results suggest that these substances, although they seem to have very characteristic tastes, are actually differentiated and recognized on the basis of their olfactory rather than their gustatory or tactual qualities.

One justification of this olfactory sacrifice is suggested by the fact that biologically one of the most important functions performed by smell is that of aiding in the discrimination of food. Through smell the animals perceive at a distance a substance which may offer itself as possible food. Biologically, the immediate guide to the acceptance or refusal of food is the sense of taste. In so far as smell is in part a subordinate servant in this matter, and hence becomes easily associated with such reactions as "eating" or "not eating," no injury is produced through the occasional confusion of the two modes.

We have thus reduced the rich manifold of taste to the qualities of sweet, salt, sour, and bitter,—four meager qualities as compared with the numerous unanalyzable qualities of various of the other sensory modes. We have now to show by what logic, through what technic, and on the basis of what evidence, we are compelled to grant to taste four qualities rather than two or twelve,

and why the final grant consists of these particular four rather than others.

Psychological Analysis of the Taste Qualities

As Chatin long ago observed, "The three senses,—taste, touch, and smell,—are so intimately combined that they seem to refuse to yield themselves to minute analysis." These associations seem to be even stronger than those between the various taste qualities, of which Ladd and Woodworth have remarked, "On the whole it appears as if the four tastes were rather isolated from each other, each representing almost an independent sense. There is much blending, to be sure, but the amount is apparently no greater between one taste and another than between tastes and odors."

We may now fairly ask how these four qualities may be made to reveal their elementary and independent character, once we have eliminated the complicating factors introduced by the intrusion of qualities from other senses.

The first appeal is to common observation and experience, according to which the four taste qualities,—sweet, sour, salt, and bitter,—stand out as conspicuous classes within which may be placed a great variety of "taste blends." Thus many substances, while having more or less distinctive flavors, resemble each other in that un-

analyzable quality which we call sweetness. The only question here is whether or not we should also include qualities other than these four as ultimate and irreducible. If we refer back to the lists of tastes proposed, we find that many of them are such as can be shown to be analyzable into one or more of these four qualities, plus the intrusion of tactile, thermal, kinæsthetic, and olfactory qualities. Such tastes as nauseating, aqueous, astringent, styptic, putrid, etc., are easily ruled out on this score alone. Introspectively, by simple experimental variation, or by casual observation, the complex character of many of these tastes is easily revealed, and when the non-gustatory components are eliminated the residue falls readily under one or other of our four qualities.

These reductions are borne out by definite experiment. The tactile (touch), thermal (temperature), and kinæsthetic (movement) factors are kept constant and reduced to a minimum by applying minute amounts of various solutions to single papillæ or very small regions of the tongue. Smell may be, under these conditions, in great measure eliminated by closing the nostrils with cotton or wax, and by letting the tongue be somewhat advanced beyond its usual position. When these conditions are observed, it is found that the main sense qualities experienced are those of salt,

sour, sweet, and bitter, along with such touch sensations as may be unavoidable. Temperature may be eliminated by having the solutions maintained at the temperature to which the tongue is already adapted.

The evidence on this point is not absolutely consistent. Some observers, for example, feel impelled to add metallic and alkaline to the group, making six elementary qualities instead of four. Other observers,—most, in fact,—are persuaded that the metallic and alkaline qualities represent mixtures of the salt, sour, sweet, and bitter, along with unavoidable sensations of touch and smell. Thus, by a suitable mixture of strong solutions of salt and sweet substances, the alkaline taste may be very well produced. "It has been suggested that the metallic taste is due to the simultaneous development of salt and sour tastes. The failure to produce exact alkaline and metallic tastes synthetically is in part due to the difficulty of imitating the tactual and other sensations with which they are bound up." Still other observers are convinced by careful elimination of smell sensation that the unique character of the alkaline and metallic qualities is really a question of odor.

By the application of specific drugs to the organ of taste further indications are secured that these four qualities, unanalyzable to introspec-

tion, also function in relative independence. Thus, the juice of gymnema leaves temporarily destroys the qualities of sweet and bitter, while sensitiveness to sour and salt remains unimpaired. "The true acid or sour taste may be separated from the astringent effect which accompanies it by painting the tongue several times with a five to ten per cent solution of cocaine. Cocaine first abolishes the sour taste, and after several minutes begins to abolish the astringent action of the acid solution. Later, the sour sensation begins to return, while the astringent effect is still in abeyance, so that the application of an acid solution at a certain stage during recovery enables the true taste character of sour to be differentiated." It is also reported that when gymnemic acid and cocaine are applied to the tongue, the one abolishes the sweet and the other the bitter, thus leaving the two other tastes relatively unimpaired. Certain mixtures seem to paralyze both sweet and bitter, but the former sooner than the latter.

Distribution of the Taste Qualities

To these four elementary tastes we are not equally sensitive on all parts of the sense organ. Roughly speaking, sweet is best tasted at the tip of the tongue, and many forms of candy are prepared so as to allow as much as possible the employment of this part of the taste

organ. Bitter, on the other hand, is best tasted at the back or root of the tongue, which explains why many substances do not taste bitter until we have swallowed them. The edges of the tongue are most sensitive to sour, while in adults the central area does not commonly yield taste qualities at all. In children, however, the taste buds extend not only over the whole surface of the tongue, but are also found in the walls of the cheek, the palate, and even on the larynx and epiglottis. Titchener has suggested that these facts may explain "the childish tendency to take big mouthfuls."

Attempts have been made to determine whether these elementary taste qualities depend on separate taste buds or papillæ. Experiments show it to be true that some points respond only to sweet, sour, etc. But there are others which yield two or three or even all four qualities, while some yield no taste at all. In one such experiment thirty-nine papillæ, in a certain region, were separately stimulated by acid, sugar, salt, and quinine. Of these thirty-nine, thirty-one responded to salt, and the same number to sweet, twenty-nine to sour, twenty-one to bitter. Four yielded no taste at all, one responded only to bitter, and one to sweet. In another case of one hundred and twenty-five papillæ examined by solutions of sugar, quinine, and tartaric acid,

sixty gave sensations of all three qualities (sweet, sour, bitter), twelve gave both sweet and sour, twelve sour only, seven bitter and sour, four bitter and sweet, and three sweet only. None of them seemed to give a bitter quality alone and this seems to be the general rule.

It is of course difficult in these experiments to restrict the application of the stimulus to single taste buds or even to single papillæ. But these experiments, along with the effects of drugs which we have already described, suggest that the taste buds are not all alike in function, even though they seem quite similar so far as appearance and structure are concerned.

The Vocabulary of Taste

Several investigators have been interested in the study of the taste names found in different languages and communities. It has been suggested that such a study might throw light on the order of development of the various taste qualities.

Kiesow found that both children and adults quite commonly confused bitter with salt and sour. Myers found, in studying the taste names of primitive people in the region of the Torres Straits, that they had no word for bitter. In some primitive languages the same word is used for sweet and salt. When there is a word for

salt it is usually some derivative of the word for sea water. Salt and sour are also often confused. In Polynesia, indeed, a single word is used in describing salt, sour, and bitter tastes. This is analogous to the fact that in primitive languages it is often found that the same word is used to indicate blue and black.

Attempts to argue from these facts of vocabulary to facts of sensitiveness and order of development are, of course, open to many sources of error. As Myers points out, "The differences between sour and bitter are considered less striking than their common unpalatability." It has often been pointed out that in our own language sweet is probably the only taste word that had from its very origin a gustatory meaning. In some languages even the word for sweet means literally "tasting good."

Vocabularies do not develop in order that structural and functional facts may be recorded for the information of forthcoming scientists. Words arise in response to the demands of practical life. It is practically more important that some substances "taste good," and others "taste bad," than that there are just four elementary taste qualities. Hence for certain primitive circumstances two taste words are all that are needed in ordinary conversation. It by no means follows from this that the salt, sour, and bitter,

which all fall in the "bad taste" category, are not discriminable from one another by the taste organs of the savage. It would be just as cogent to insist that, since we have only one word for the taste of various sour things, all of these various tastes must be indistinguishable to us.

Nor is the argument safe that those sense qualities for which specific names exist must be more ancient than those qualities for which names are borrowed. Many of our color names are not primarily color names at all,—as violet, rose, olive, turquoise, lemon, straw, orange, and, perhaps, pink and green. Red, blue, and yellow seem to be more essentially color names. Yet, it is difficult to suppose that an organism sensitive to red and yellow should not also be sensitive to orange, which may be produced by a mixture of red and yellow light.

In the case of the odors, which we have every reason to believe are extremely ancient sense qualities, we have in our own language almost no exclusively olfactory names. Smells are designated by the objects with which they are associated,—as lilac, lavender, musk; or names are borrowed from other sensory modes, as sweet, sour, heavy; or still more descriptive and perceptual names are used, such as fresh, flat, rancid, foul, nauseating. Interesting as the vagaries of vocab-

ulary may be, they yield very little information concerning the primitiveness, elementariness, sensitiveness, or distribution of the various taste qualities.

CHAPTER II

The Organization of the Tastes

System and Organization in Other Senses

In the case of some of the sensory modes it is possible to arrange the various elementary qualities in a schema or graph, representing in a diagrammatic way their relations to each other, the results of their combination, their influence on each other, etc.

Thus, in the case of vision the conventional "color pyramid" expresses the various relations between the different elementary colors and the different degrees of brightness. Red, yellow, green, and blue occupy the corners of the base of a double pyramid. The upper apex represents white and the lower apex black. On the side between red and yellow are found the various oranges which result from mixing red and yellow light in varying proportions. On the remaining sides are represented the combinations of yellow and green, green and blue, blue and red. Along the vertical axis range the different grays. Cross sections of the pyramid indicate, at different

levels, the result of mixing the different colors with these grays, thus yielding the tints and shades of the colors. Along the base, the colors which are at the extreme ends of any diagonal passing through the center are complementary,—they neutralize each other when mixed and under other circumstances each tends to induce the other by contrast. The visual manifold may thus be adequately schematized on a three-dimensional figure.

In a similar way the various tones, in the case of hearing, may be arranged along a one-dimensional line, which represents the tonal scale. Is it possible to arrange in any such systematic way the elementary taste qualities so as to indicate their relationship to each other? Before suggesting such a diagram it will be well to have in mind just what relationships the various taste qualities do as a matter of fact display.

Taste Mixtures and Compounds

The testimony of daily experience would probably be at once that the various elementary tastes may combine to produce new tastes of a more complex or even of a unitary character. Thus, the taste of lemonade is distinctive enough. Yet even casual observation suffices to show that the sweet and the sour components have by no means lost their identity, since each can be singled out

in attention and recognized as the familiar elementary quality. Red and blue may fuse to produce a violet or a purple from which the original elements can by no means be singled out and identified through direct inspection. But it seems to be the rule that tastes do not behave in this way, although the demands of daily experience do not readily lead us to discover the fact. "Think, for instance," writes Titchener, "of the flavor of a ripe peach. The ethereal odor may be ruled out by holding the nose. The taste components,—sweet, bitter, sour,—may be identified by special direction of the attention upon them. The touch components—the softness and stringiness of the pulp, the puckery feel of the sour—may be singled out in the same way. Nevertheless, all these factors blend together so intimately that it is hard to give up one's belief in a peculiar and unanalyzable peach flavor. Indeed, some psychologists assert that this resultant flavor exists; that in all such cases the concurrence of the taste qualities gives rise to a new basic or fundamental taste, which serves, so to say, as background to the separate components. There is, however, no need to make any such assumption. It is a universal rule in psychology that when sense qualities combine to form what is called a perception, the result of their combination is not a sum but a system, not a patchwork but a pattern. . . .

Hence, just as it would be absurd to say that the plan of the locomotive is a new bit of steel or the pattern of the carpet a new bit of colored stuff, so is it wrong to say that the peach character of a certain taste blend is a new taste quality."

The mixture of stimuli provoking two taste qualities does not, then, produce intermediate qualities such as the orange which results from the mixture of red and yellow. Instead, in this case, the two qualities do one of these three things: (a) they may remain separate and distinct; (b) they may fluctuate individually and alternate with each other in their appearance; (c) they may tend to neutralize each other. If the stimuli are very intense, oscillation is the common result. If the stimuli are weak, some degree of neutralization is reported to be the rule. Only in one case, namely, the mixture of sweet and salt, does a new taste seem to emerge, which does not resemble either of the original qualities. Kiesow finds that such a mixture, in the case of weak solutions, gives rise to a quality described as "flat," "vapid," or "insipid,"—the alkaline taste which we have already considered.

Compensation, Antagonism, and Neutralization

In the case of color, there may be found for every quality or mixture an opposite quality or mixture which when combined with the former

either completely neutralizes it or at least reduces its intensity. Thus blue and yellow, of the proper tones and proportion, cancel each other, leaving only an experience of gray. So do a certain olive color and a particular violet, a certain orange and a particular bluish-green, a certain red and a particular green.

We have already suggested that in case of weak taste qualities a similar effect is present. "With the low intensities there is in most cases a partial compensation, which is least for sweet and sour, better for salt and bitter, better still for sour and bitter, sour and salt, sweet and bitter." These facts are utilized in daily life in the countless combinations of dressings, sauces, seasonings and condiments used in the preparation of food. We take sugar with our tea, our coffee, our chocolate, our strawberries, our grapefruit, and our lemon juice, and realize that it to some degree counteracts or neutralizes the bitter or the sour taste of these foods in their original form. "Salt corrects the sweetness of an over-ripe melon." In our salad dressings, sauces, gravies, relishes, and bitters we find the means of reënforcing or toning down the taste qualities to suit our own particular fancy.

In part, of course, these effects are not achieved through the mere process of neutralization. The addition of touch qualities, such as the pucker of

vinegar, the sting of pepper, the bite of mustard, and the burn of onion, plays its own part in the constitution of a flavor, regardless of their compensating influence on the pure taste qualities.

In line with the fact that taste and odor are easily confused, and contributing perhaps to this confusion, is the fact that tastes and odors are related to each other through their antagonism, almost if not quite as definitely as are the qualities within each of the separate modes. Thus, the sickening odor of many medicines is somewhat palliated if they are taken in fermented juices or with the sour acids of fresh fruits. "Quinine, which tastes bitter and has no smell, is corrected by essence of orange peel, which has an aromatic smell and no taste." Titchener pertinently remarks that these results may in part arise from the simple process of distracting attention from an unpleasant item to a more agreeable part of the experience. On the other hand, the special effectiveness of the introduction of odors into the complex rather than pleasant sights and sounds suggests that the results in the case of taste and smell are not solely a matter of attention, but are in part, at least, dependent on the essential relationships between the qualities of these two modes of sensation. In the chapter on "The Evolution of Taste" certain light is thrown on the closeness of these relationships by our knowl-

edge of the intimate biological connection between taste and smell. In certain lower forms of animal life it is indeed quite impossible to draw any clear line between these two features of "the chemical sense."

In general, then, although the facts of compensation, antagonism, and complementariness are to be observed within the field of the taste qualities, the relations disclosed are by no means as definite nor as systematic as they are in the case of vision. For a given primary color quality there exists only one other elementary quality which stands to it in the relation of antagonist. But we have seen that in the cases of both sour and bitter there is at least some degree of antagonism with all three of the other qualities, while both sweet and salt antagonize in some degree both sour and bitter. Moreover, at least the sour, the bitter, and the sweet appear to show antagonistic relations to certain qualities of smell.

In none of these cases has there been presented clear evidence showing the ability of one quality to totally efface another, so that no taste whatever is present. In the case of colors, however, the result of such combinations in the right proportions may easily be a total absence of color quality. It is true that occasional instances of such effects in taste have been reported, but the

general rule seems to be that the extreme degree of neutralization leaves an experience which is recognized as a taste, but which is described as "flat" or as "insipid." It is possible, of course, that this "insipid" taste quality is the tactile and kinæsthetic residue of the total experience, much as the "gray" which results from the combination of complementary colors may be described as the brightness residue of the total momentary effect. But in the latter case the residue would be distinctly "visual" although not "color." In the case of taste nothing corresponding to the "brightness" of vision is recognized, and the residue as we have described it would consequently belong to a different mode of sensation.

Contrast Phenomena

The phenomena known as contrast are very familiar sense experiences. Not only is it true that in the fields of perception and feeling the tall, the good, the wholesome, the fast, the daring, and the pleasant have their qualities enhanced when they accompany or follow upon the diminutive, the wicked, the foul, the slow, the cowardly, and the disagreeable; in the case of more simple sense experiences also contrast effects are often both immediate and striking. The apparent temperature of the air or water varies with the conditions from which we emerge into them. The

sudden calm after a thunderstorm seems even more empty than the same conditions in Indian summer. The palest complexion assumes a moderate rosiness if green ribbons and fabrics are suitably arranged about or near it. Even a pure gray strip of paper becomes a rich pink line or a yellowish band when placed across a background of saturated green or blue.

Daily experience entails many such instances of contrast in the case of the taste qualities as well. A ripe apple may surprise us by its unexpected sourness if we come to it direct from a box of bonbons. Experiments designed to investigate the presence and character of taste contrasts are especially interesting and their results are in many ways curious. If, under proper experimental precautions, a salt solution is applied to one side of the tongue and a drop of tasteless distilled water is simultaneously applied to the other side, the tasteless water is reported as sweetish. If, instead of the distilled water, one apply a sugar solution of such weakness that its taste could not under ordinary circumstances be recognized, the sweetness becomes clearly apparent. Under the same circumstances a solution otherwise producing a weak sensation of sweetness is reported as being "very sweet." The salt solution, that is to say, induces by contrast the quality of sweetness in tasteless substances and enhances the de-

gree of an otherwise weak quality aroused at another region of the tongue.

In much the same way a sugar solution induces saltiness, or sourness, or perhaps bitterness, according to the individual, the occasion, and the circumstances. Sometimes the salt induces a sour instead of the sweet. The bitter, however, seems unable to induce other qualities by contrast, and is at least seldom induced by the other qualities.

In this as in other respects the bitter quality seems to show idiosyncrasies. Thus, it is generally accepted that no papillæ are ever sensitive only to bitter stimuli. Many primitive languages are said to contain in their vocabulary no word for bitter: it is not uncommon in daily experience to find bitter confused with sour; bitter seems to be especially easily antagonized by certain odors; it does not display striking contrast phenomena; and its reaction time is exceptionally slow.

The type of contrast which we have thus described in the case of the tastes is known as *simultaneous contrast.* Both stimuli are applied at the same time to different parts of the sense organ. What is known as *successive* contrast can also be experimentally produced. Here one of the stimuli follows the other after an interval in which nothing is applied or, still better, in which the mouth is carefully rinsed with water. This is the type of taste contrast with which we are

most familiar in daily life. The same contrasts may be induced experimentally by this method as result from the simultaneous method. But the inducing stimuli in this case must be rather more intense than is necessary for the production of simultaneous contrasts. In much the same way in perception as in sensation the contrast between two extremes or opposites is better realized when both are present together than when one follows the other after an interval.

The general facts of taste contrast are succinctly summarized by Titchener in the following way:

(1) Salt and sour contrast: the sour induced by salt being clearer and stronger than the salt induced by sour.

(2) Sweet and sour contrast: the sweet induced by sour being clearer and stronger than the sour induced by sweet.

(3) Salt and sweet contrast: the sweet induced by salt being clearer and stronger than the salt induced by sweet.

(4) Bitter shows no contrast at all.

(5) The order of qualities, as regards ease of induction, is sweet, sour, salt, bitter.

After Images of Taste

Suggested by the phenomena of contrast are the somewhat related facts of after sensations or

after images, as they are sometimes called. When one looks for a moment at a candle or other source of light and then quickly extinguishes it or looks away from it, one still continues to see, for a time, a luminous form, which may persist for a considerable time after the removal of the stimulus. In such a case the color and brightness of this after image may be the same as those of the original object, and the after image is hence said to be *positive*. Under certain conditions the colors of the after image are complementary to those of the original and the brightness relations of the various parts are reversed. The after image is then said to be *negative*. Or if after looking at a colored object one transfers his gaze to a gray expanse there appears upon this gray field an outline of the original object, with colors which are complementary or antagonistic to those of the original. After sensations of pressure arising under special conditions have been described, and positive after effects of warm and cold stimuli seem also to be demonstrable. Even after sensations of sound, somewhat weak, transitory, and by no means easily detected, have been described. In all these cases except vision the after sensations are of the positive type only.

In the case of taste, and of smell also, it is difficult to investigate the presence of such after sensations, inasmuch as it is by no means easy to be

sure that some trace of the stimulus does not remain in or near the sense organ. An experience reported as a positive after sensation might easily enough represent only the effect of persistent stimulation by these traces of the substance. At least one investigator is convinced that in his observations of taste experiences "the sensation continued after the tongue was so carefully dried off that no particles of the tastable substance were left." Similarly, experiences of tastes being "left in the mouth" are very common. But our inadequate control over the disposition of the sapid substance and the complicated chemical relation which exists between various substances and between some substances and the natural juices secreted in the vicinity of the taste organ makes it impossible to assert with certainty either the presence or the absence of after sensations of taste.

The Schema of Taste Relations

The foregoing facts concerning the phenomena of mixture, fusion, antagonism, contrast, and after sensation show at once the impossibility, in our present state of knowledge, of arranging the taste qualities in any such systematic scheme as is represented by the color pyramid and the tonal scale in the cases of vision and hearing. It by no means follows, however, that such orderly arrangements have not been attempted.

Kiesow, one of the most famous students of the sense of taste, proposed that a circle with a vertical and a horizontal diameter indicated would best represent the various relations between the taste qualities. At top and bottom would stand

Fig. 1

salt and sweet; to left and right, bitter and sour. Along the horizontal diameter would be placed the mixtures of bitter and sour, and along the vertical diameter would range the various results of mixing salt and sweet. The mixtures of salt-sour, sweet-sour, bitter-sweet, and bitter-salt would stand in their appropriate places about the circumference or periphery of the circle.

Wundt tentatively adopts a similar scheme when he says: "The system of taste sensations is, accordingly, in all probability to be regarded as a *two-dimensional* continuity, which may be geometrically represented by a rectangular surface at the angles of which the four primary qualities are placed, the various mixed qualities being placed along the side and on the inner surface."

To such suggestions, however, Kuelpe objects that: "There is no indication of a continuous transition between the four qualities which tastes appear to present, as there is between the qualities of tone sensations. They form, not a one-dimensional manifold, but a discrete system of unknown relations."

Titchener, one of the most careful students of sense experience, is less emphatic, but he "doubts whether, in the present state of our knowledge, this idea (that of Wundt) can be accepted." He doubts "whether the sweet-sour of lemonade stands to its originals as blue-green stands to blue and green, or as orange to red and yellow; and also whether bitter should lie in the same plane with the other three taste qualities. We must suspend judgment; in the meantime, Kiesow's figure provides us with a working hypothesis."

Ladd and Woodworth align themselves with Kuelpe and conclude that, "there is no clear indication that the tastes can be arranged in a linear

scale, as the primary colors are, nor that any taste stands to any other definitely in the relation of opposite or complementary. On the whole it appears as if the four tastes were rather isolated from each other, each representing almost an independent sense."

CHAPTER III

The Sensitiveness of Taste

Various Measures of Sensitiveness

In a general way it is well known that exceedingly weak solutions of many substances are sufficient to provoke sensations of taste. It is also known that weak tastes which some individuals are able to detect or to recognize correctly go quite unobserved by others. The same thing is true of differences between tastes. The connoisseur is sensitive to minute differences in the flavor of wine, tobaccos, and sauces. Through practice the expert taster of these substances acquires a skill which is quite incomprehensible to the inexperienced. In part only is such skill a matter of special sensory activity. It is in large measure a matter of perception rather than one of sensation, —a knowledge of what signs to look for and how to interpret these signs,—rather than an increased sensitiveness to stimuli. In the same way the skilled gardener, hunter, or scout is alert to the significance of particular signs and clues and this alertness and apt interpretation may make him

appear to have senses of exceeding acuteness, although this may by no means be borne out by actual measurements.

The psychological problems involved in the measurement of keenness of taste are mainly two in number. One problem concerns itself with the question, What is the faintest stimulus that can be sensed,—the weakest taste that can be appreciated? The other concerns itself with the sensitivity to difference between tastes, and would be expressed by some such question as, How slight a change in the amount or intensity of the stimulus is required for one to be able to perceive a change in the intensity of the taste sensation?

Unfortunately for our knowledge of tastes, both these problems are very difficult to approach experimentally. Whether or not a given weak stimulus will provoke a taste sensation depends on very many things other than the strength of the solution. The amount of solution applied, the extent of surface excited, the duration of the application, the temperature of the solution, the state of rest or movement of the sense organ, and the nature of preceding stimuli, among other things, are important.

The Threshold of Taste Sensation

Numerous investigations have concerned themselves with the task of discovering the weakest

solution of various substances that will provoke their respective sensory qualities. The main results of these studies have been the demonstration of two facts, namely, that exceedingly weak stimuli may arouse sensations of taste and that this minimum solution varies greatly in amount according to the substance which is in question.

Valentin, in 1842, measured the lower threshold for solutions of sugar, salt, quinine, and sulphuric acid and found the following proportions to represent the least amounts able to arouse the corresponding sensation:

Sugar	1.200	parts to	100	parts of	water	
Salt	0.300	"	"	"	"	"
Acid	0.001	"	"	"	"	"
Quinine	0.003	"	"	"	"	"

Numerous other investigators have reported figures of this character. Thus, Nichols and Bailey give the following as averages of the lower thresholds in the case of measurements on forty-six women:

Sugar	1 part to	204	parts water
Salt	1 part to	2,000	parts water
Acid	1 part to	3,300	parts water
Bitter	1 part to	456,000	parts water

It is neither profitable nor interesting to draw close comparisons between the various sets of

measures, since they vary considerably with the substance used, and since, after all, as one writer remarks, "the experiments are chiefly valuable as gratifying our curiosity." Various students of individual differences have sought to determine the presence of sex differences, age differences, race and group differences, in these minimal taste stimuli. But the incidental factors are so numerous and so beyond experimental control that, if such differences exist, it has never been possible consistently to demonstrate their nature or amount.

Relative Sensitivity of Taste and Smell.

A recent investigation by Parker and Stabler was directed toward a question which possesses a certain interest. Reasoning that, since taste and smell are both "chemical" senses, it might be possible to compare their respective sensitivities in terms of the strength of solution required to affect them both, they attempted to make such comparison in the case of one substance. Pure ethyl alcohol is a substance which has both a distinctive taste and a distinctive odor. These investigators found that the minimum amount of this substance that could be sensed by taste was 24,000 times as great as the least amount that could be detected by odor.

The Discrimination of Tastes

In the case of our second general question, that concerning the amount of change in the strength of solution required to produce a felt difference in the intensity of the taste sensation, various difficulties are involved. In the first place, there is no known way of measuring the intensity of that mode of stimulation which may be responsible for the excitation of the taste bud. In such cases as the sensibility to weight and light it is easily possible to measure the intensity of the stimulus in terms of pounds, candle power, or similar physical units. In the cases of temperature and sound the problem is much more difficult, since we do not know precisely what aspect of the stimulus should be used as indicating the intensity of the process at the point of stimulation. Taste and smell offer still greater difficulties, inasmuch as we do not know even with moderate certainty the real nature of the stimulation,—whether, for example, it be mechanical or chemical, or both. Consequently, although it is possible to state that in general a change in the stimulus intensity required to produce a sensation change which will be correctly reported in a certain percentage of the trials is 1% for light, 33% for sound, 5% for lifted weights, no such coefficients of change can even be suggested for taste and smell. Only the

general statement can be made that, within limits, increased strength of solution means increased intensity of sensation.

Adaptation and Fatigue

Curious phenomena in the case of all the senses are those known as adaptation and fatigue. It is a familiar experience that the illumination of a room which seems upon entrance to be yellowish quickly comes to appear merely light. After a few minutes wearing colored goggles the tinge they give to objects seems to disappear and we say we have become "adapted" to the color. "We become rapidly adapted to a constant stimulus so that we fail to notice the weight of our hats, the temperature of the room we are in, the odors of the subway." Searching for spectacles which meanwhile perch upon the nose is the result of adaptation. A related phenomenon is the fact that a darkened room which on entrance seems perfectly black comes in time to show its contents as more or less clearly marked off from one another.

Some adjustment—in the sense organs, perhaps, or perhaps in the brain centers—takes place in the presence of a constant stimulus. The general result of this adjustment is that the particular sense quality involved fades away: colors tend toward gray, pressures tend to disappear,

temperatures tend toward a neutral point, and sounds become indifferent. This adjustment is not fatigue in the usual sense of the word. The area that has become adapted to a given pressure is still sensitive and will feel even a lighter weight if this be substituted for the one to which it has become adapted. It is adapted to a continuous stimulus, but it is sensitive to any change in the stimulus.

In the case of smell it is notorious that odors constantly present soon cease to be observed or even to be observable. Even the most disagreeable and insistent odors fade away in time. In a few minutes stale cheese comes to have no discernible odor, while the odors of tobacco smoke and various perfumes disappear equally quickly. In this sense adaptation seems to be much more like exhaustion or fatigue than in the cases of sound, sight, and pressure, and it may require a considerable interval of freedom from the stimulus before the quality returns.

The laws and effects of adaptation are by no means the same for all the senses. Thus, in the case of smell, adaptation to certain odors seems to increase our sensitivity to other odors. In the case of taste the effects are by no means clear nor consistently reported by different observers. In general it seems to be true that the effect of adaptation to a given taste quality has no

demonstrable effect on the remaining qualities, and that this effect, as in the case of smell, is of the general character of exhaustion. Taste, along with smell, seems to have not yet developed any peripheral or central mechanism whereby adaptation may take place without actual loss of sensibility.

Acquired Tastes

In a very different sense the word "adaptation" is often employed to express the phenomenon of habituation in the case of "acquired tastes." Here the habituation is not to the taste quality, in a sensory sense, but represents a change in the feeling or affective tone which characterizes or accompanies this quality.

The easier case to understand is that in which the continued indulgence in a substance, such as ice cream, candy, tobacco, sets up organic effects which have their unpleasant accompaniment. Here it happens that a taste originally very pleasant becomes indifferent or even disgusting. The unpleasantness in such a case is rather easily seen to arise, not from a taste quality alone, but from the total state of the moment. On a later occasion the first appearance of the taste quality may, by well-recognized associative mechanisms, arouse the organic revulsions or memories of them, with the attendant disagreeable effect. The

originally agreeable taste then appears to have become disagreeable.

Cases of the reverse order are equally familiar, in which a taste originally unpleasant comes, with repetition, to lose its disagreeable character, or even to become distinctly pleasing. Indeed, in many such cases habituation results in the establishment of a craving for the quality which was originally repulsive. Here the repetition of the taste quality seems to set up defensive adjustments and adaptations of a profound organic kind rather than the earlier protective reactions of refusal and rejection. Once this adjustment or adaptation takes place the presence of the original stimulus is called for as part of the new condition of balance, and the craving, or appetite, results. In this account, it must be confessed, we speak in terms of vague generalities, since it is not easy to state the precise nature of these biological adaptations. But their existence in the case of many users of such things as olives, garlic, tobacco, liquors, and various drugs is a matter of common experience.

The Early Development of Taste

In the chapter on "The Evolution of Taste" it will be shown that very early in the development of the forms of animal life there is present a form of sensibility to that type of stimulation

which, in our own experience, provokes sensations of taste. The "chemical" sense is thus seen to be a very primitive mode, and adjustments to chemical factors in the environment are present at a very low level of organic development. It is a general rule that capacities which appear thus early in the animal series (phylogeny) also appear relatively early and relatively complete in the development of the individual (ontogeny) of more elaborate forms. So far as we are able to discover, this rule holds for the development of the sense of taste. In a number of cases individual infants have been carefully observed in order to note the order of development of the various senses and the adjustments to stimuli in these different modes. In several cases large numbers of newborn infants have been tested immediately after birth, with the same questions in mind.

These studies show that not only is sensibility to taste present at the time of birth, but that the newborn infant reacts in different ways to the various taste qualities. On the first experimental application of taste stimuli distinguishable reactions, such as quiet sucking, grimacing, nausea movements, facial expressions, and varied mimetic behavior, indicate that at least in a rudimentary way the various taste qualities are

responded to in a selective or discriminative manner.

Thus, Kussmaul, in 1859, tested twenty-one children with solutions of sugar and of sulphate of quinine. In general the sweet and the bitter caused "the same mimetic facial movements as are observed in adults." There seemed, however, to be certain individual differences in sensitivity, and occasionally sweet and bitter provoked facial reactions which were not distinguishable. Guezer, in 1873, studied fifty newborn infants by giving them tastes of sugar, quinine, and weak acetic acid. The sugar, as a rule, produced "pleasurable sucking," the quinine and acid produced "unpleasant 'bitter' expression and even nausea movements." Kroner, in 1882, recorded studies of the taste reactions of his own children at birth. He observed that they reacted immediately after birth to sweet and bitter with the characteristic facial expression of the adult. He was convinced that the sense of taste was at birth the best developed of all the senses.

The most elaborate study of this kind yet recorded is that of Peterson and Rainey. These observers report tests of 1,060 newborn infants, varying in nationality, color, sex, and period of gestation. The experiments included tests on all the senses. As taste stimuli for salt, sour, sweet, and bitter they employed solutions of salt, acetic

acid, simple syrup, and tincture of gentian. The tests of taste showed "with great regularity mimetic reactions to these stimuli characteristic of adults, grimaces of discomfort, or expressions of content and liking." "The gustatory nerve not only reacts differently to salt, sweet, bitter, and sour at birth, but the same mimetic reactions are observed in premature infants. This nerve is therefore ready to receive taste impressions some time before the normal period of birth."

CHAPTER IV

Time Relations of Taste Qualities

The Inertia of the Taste Organs

Many experiments have been undertaken in the effort to measure the inertia or sluggishness of the various senses. Inasmuch as the nervous structure is a physical system set in operation by the incidence upon it of external agencies, in each of its parts it requires a certain time in order to be set going; and, once set in operation, acquires a certain momentum which necessitates that a certain time elapse before it is again in a state of equilibrium. At least the sense organs all show such inertia, so that, in a given case, only a limited number of distinct sensations can be produced in a given time by successive stimulation. A measure that has often been used for expressing such facts is the maximum number of separate excitations to which the sense organ responds in a unit of time, as one second. This measure, to be sure, varies considerably with numerous conditions and circumstances, such as the nature of the stimulus, the part of the sense organ affected, its previous

condition, the intensity of the stimulation, etc. This measure, which may be said roughly to indicate the duration of a sensation (including its positive after image), is very short for touch, somewhat longer for sound, and still longer for vision. Because of the nature of the stimuli in taste and smell and the difficulty of accurately controlling their application and removal, satisfactory measures of the inertia of these sense organs have never been secured.

Reaction Time to Taste Stimuli

One fact, however, seems to be fairly clear from experiment, although it would by no means be suspected from casual observation, namely, that the various taste qualities are not equally prompt in the time required for them to appear after the application of the stimulus. Salt and sweet come rather quickly as compared with sour and bitter, the order of speed being salt, sweet, sour, bitter. How much this may depend merely on such differences as may exist in the structure and location of the various taste buds it is impossible to say. Kiesow points out that taste sensations are tardy and gradual in their appearance. If the person being stimulated be required to indicate by a signal the instant at which the taste quality appears, it is possible to measure, in very small units of time, the interval between the

superficial application of the solution and the appearance of the sensation. This is called the "reaction time" to the taste stimulus. When the stimuli were applied to the tip of the tongue Kiesow found the following figures to represent average reaction times to his different solutions:

Salt	.307	seconds
Sweet	.446	"
Sour	.536	"
Bitter	1.082	"

The reaction to bitter, which requires twice as long in the above case as that of any other quality, was considerably shorter when the stimulus was applied to the root of the tongue. This suggests that the differences found by Kiesow may in part, at least, depend on the accessibility and perhaps also on the number of such various types of taste buds as there may be.

Taking these reactions times as they stand, the average time for the four taste qualities may be said to be about one-half a second. As compared with the reaction times of other sense modes, taste is more sluggish than any other sense, with the possible exception of smell. Averaging the results of numerous observers for the range of stimulus qualities and intensities that have been employed, the comparative times are somewhat as follows:

Reaction to	sound...	.146	second
"	" touch...	.149	"
"	" sight....	.189	"
"	" taste....	.500 (?)	"
"	" smell....	.500 (?)	"

It should, of course, be borne in mind that these are but averages of figures which vary considerably with a large number of factors, although it is true that the influence of these factors can itself be subjected to precise measurement.

Determinants of Reaction Time to Taste

By way of illustration of the numerous incidental and extraneous factors that influence reaction time to the taste qualities we may instance the temperature of the solution. In what seems to have been a carefully conducted series of observations Chinaglea has recently shown the nature of this influence. As Kiesow had already found, the temperature of the solution (within the pain limits) does not influence the intensity of stimulus required to produce the weakest sensation, and hence does not modify the threshold or limen. But such changes Chinaglea showed to have a measurable influence on the reaction time to taste stimuli. Lowering the temperature of the solution below that of the mouth does not affect reaction time to salt, but it lengthens the

time for the other qualities. Raising the temperature of the solution above that of the mouth quickens the reaction to sweet, but lengthens the reaction to bitter and sour.

CHAPTER V

The Sense Organ of Taste

Comparison With Other Sense Organs

The so-called higher senses are usually differentiated from the lower on the basis of their greater intellectual value. The sense of taste is one of the lower, as compared with vision and hearing, which are of the higher group. Not only in the purpose which they serve, but also in the character of their mechanism, do the senses differ. The sense of taste differs from the sense of sight in at least three respects. First, it is a mechanism not given over exclusively to the taste function, but serves other functions as well. The visual mechanism, for instance, is very highly specialized. It consists of an elaborate mechanical device,—extrinsic and intrinsic muscles, lens, iris, etc.,—which serves to prepare the physical stimulus to act upon the real receptor portion of the sense organ, the retina. None of these parts of the eye serve any other purpose than that of vision. In the case of the taste mechanism, on

the other hand, only the receptor * portion of the mechanism is concerned exclusively in the taste function. The tongue, usually considered the most important part of the taste organ, with its great variety of movements, is a very necessary part of the speech mechanism. The salivary glands, which by their secretions put the substances entering the mouth into such condition that they may act upon the receptor mechanism, are of vital importance for the process of digestion. The small receptors imbedded within the coverings of the tongue and the linings of the mouth cavity may be considered as the only structures which perform exclusively a taste function.

Secondly, it is not easy to determine the limits of distribution of the receptor organs of taste, as one can do in the case of the eye, with its clearly defined retina, or the ear, with its organ of Corti, or even the nose, with its regia olfactoria (patch of mucous membrane). That is, there is no one organ with its attachments which can be called the taste organ. Consequently, one does not find any general agreement as to what structures ought to be included in the taste mechanism. For instance, it

* A receptor is the part of the sense organ in which the transformation from a physical stimulus to a nerve impulse occurs.

is well known that the taste function is not limited to the tongue, and that the whole mouth cavity is a more or less important part of the taste mechanism. Certain investigators are not willing to circumscribe the taste organ within such narrow limits, but extend it to the larynx, the vocal cords, and some have even gone so far as to include the membranes of the nasal cavity.

Finally, the taste mechanism is extremely simple when compared with the so-called higher senses, especially that portion of it whose function is to prepare the stimuli to act upon the receiving mechanism. The taste organ is generally believed to represent a stage in evolution very near to the original structures from which all of the sense organs have developed. That is, looked at from the evolutionary point of view, it is a more primitive and less highly developed mechanism.

The Salivary Glands and Their Activity

Consider first those portions of the taste organ which perform the mechanical function of preparing the stimulus to act upon the receiving mechanism or the sensory ends of taste. Most important of these are the salivary glands and the tongue. The latter through its movements facilitates contact of the taste substances with the sensory ends of taste, and the former secrete saliva, which dissolves the sapid substances, re-

ducing them to the liquid form necessary for arousing taste sensations.

The salivary glands and their secretions are of interest to the student of taste only in so far as their activity forms a necessary step in the taste process. In this connection it must be remembered that the chief function of the saliva is the part it plays in the process of digestion. As suggested above, the function of the saliva in the taste process is merely that of dissolving or transforming solids into liquid form. Consequently, the chemical constitution of the saliva and the detailed structure of the glands are aside from our interest. The action of these glands, three in number, and called the parotid, the submaxillary, and the sublingual, is of the reflex type. The stimuli for the reflex are numerous, and, it appears, are not the same for all of the glands. For instance, the submaxillary glands are said to secrete upon the presence of certain foods, acids in the mouth, the chewing of meats, etc. On the other hand, the stimulus for the parotid gland has been shown by Pavlow to be the presence of dry substances in the mouth. If no distinction is made between glands, it may be said that watery foods cause only a slight flow of saliva, while dry foods cause a large flow of saliva. One sees, then, a set of reflexes which not only promote the digestion of foods, but which also tend to make them

tastable. These two functions are not entirely separate ones, for it has been shown by experiment that the tastes of various foods are determining factors in causing and regulating the flow of gastric juice in the stomach.

Although the action of the glands is reflex in character, and is due to the stimulation, by objects in the mouth, of the glossopharyngeal and lingual nerves supplying the mouth and tongue, this is not the only means by which the reflex can be excited, or the flow of saliva produced. It is a matter of common knowledge that the *sight* of various objects—a lemon, for instance—will cause a copious flow of saliva, and, further, that certain mental states, such as fear, anxiety, and the like, may cause reduction of the flow of saliva, with the resultant dry mouth, the cleaving of the tongue to the roof of the mouth, and other unpleasant effects of lack of saliva. These last forms of activity must be due to impulses coming to the glands or to the secretion center in the brain stem from the cortical regions of the brain, and they are called psychic reflexes or conditioned reflexes. That is, the reflexes are conditioned upon the experience of the individual somewhat as follows: If the visual experience of a lemon is followed a number of times by the taste of the lemon and the reflex excitation of the salivary glands from the presence of the acid in the mouth,

it may come about that the sight of the lemon unaccompanied by its entrance into the mouth will cause the flow of saliva. The stimulus to the reflex activity has changed from one of contact of a substance with the mucous membrane of the mouth to a visual stimulus. As a result of the development of these psychic or conditioned reflexes, if one sees a certain kind of substance that he is going to taste, the flow of saliva necessary to reduce it to a tastable form is brought about even before the substance has entered the mouth. Pavlow cites a case in which a handful of clean stones placed in the mouth of a dog produces a very slight flow of saliva, while the same material in the form of fine sand causes a copious flow of saliva. Such cases as this indicate the great delicacy with which the salivary secretion is adapted to the condition of the substances entering the mouth. No sapid particles entering the mouth dry can stimulate the taste mechanism except through the mediation of the saliva.

The Tongue: Its Muscles and Covering Membranes

Considered as a part of the taste mechanism, the tongue is a body of irregular shape, occupying a large portion of the mouth cavity. It is composed largely of muscles, covered with a mucous membrane very similar to that which

lines the whole mouth cavity. It has an upper, or superior surface, a lower, or inferior surface, two sides, and a tip, in addition to the base, or region of its fixation. The muscles are of interest in that they give to the tongue its great variety of movements, and the membrane-covered surfaces are of especial interest, because in them are found by far the greatest number of the nerve endings or the sensory ends of taste.

The tongue is made up of seventeen muscles, acting in three planes—vertical, longitudinal, and transverse. Separating these muscles one from another are layers of fatty tissue, enabling the muscles to glide easily over each other. Fifteen of these muscles are extrinsic in the sense that one end of each has its point of attachment outside of the tongue. It is these muscles especially that give the tongue its great motility. By the contraction of single muscles or contraction in various combinations the tongue is protruded or drawn back, the tip raised or lowered, the dorsal surface pressed against the roof of the mouth or withdrawn toward the floor of the mouth, the tongue protruded and turned to one side or the other. In addition to these extrinsic muscles there is a pair of intrinsic muscles, each having both points of attachment within the tongue. By their contraction the sides of the tongue are raised and drawn together.

These muscles are richly supplied with blood vessels and receive an especially large supply of nerve fibers from the hypoglossal, which is known as the motor nerve of the tongue, and some from the lingual branch of the seventh, or facial, nerve.

It is generally believed that the tongue movements serve the sense of taste only as they facilitate contact of the sapid substances with the real taste endings; for instance, by pressure of the tongue against the roof of the mouth, and by its protrusion from the mouth to receive the stimuli upon its surface. However, it has been asserted by some investigators that the movements are of more direct use in the taste process, in that tongue movements in themselves tend to increase the sensitivity of the taste mechanism. But careful experiments in which the tongue was rendered motionless during tasting show that taste sensitivity is just as great as when the tongue is free to move.

By far the most important portion of the tongue is its mucous covering. This varies considerably in character in different regions, being thickest and toughest on the superior surface where it comes into contact with objects taken into the mouth, and thinnest on the inferior surface where it is ordinarily protected from such contact. On the sides and tip it is moderately thick and tough. The tongue covering has a highly

complex structure. Two distinct layers, or strata, are commonly described: the more superficial, or epithelial layer, and the deeper layer, called the chorion. The first, or epithelial, layer contains all of the sensory endings concerned in taste upon the tongue, and these will be described later. The second is more complex and consists of connective tissue, a great network of blood vessels, nerve fibers, and numerous glands and their ducts which open upon the surface of the tongue. Upon the more superficial surface of this inner layer there is an extremely large number of slight elevations. These are apparent to the unaided eye upon the tongue surface, since the epithelial layer of the membrane follows very closely the contour of this deeper layer. These elevations are called papillæ. (Fig. 2.) They vary in size and shape and are quite unevenly distributed upon the surface of the tongue. On the inferior surface there are none, while on the superior surface they are most numerous. With the aid of the papillæ on this surface the tongue can be divided into two parts, an anterior or horizontal portion and a posterior or vertical portion. The former includes about the forward two-thirds of the tongue and the latter the posterior third. These two parts are separated by a row of relatively large elevations, about ten or twelve in number, and arranged in the shape of a V, with the open portion of the V turned for-

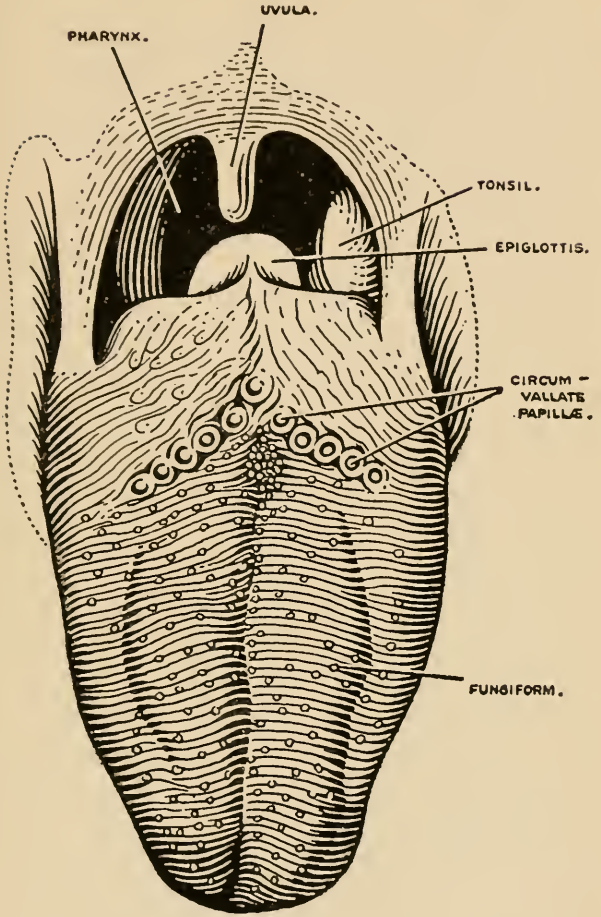
UVULA.
PHARYNX.
TONSIL.
EPIGLOTTIS.
CIRCUM - VALLATE PAPILLÆ.
FUNGIFORM.

Fig. 2.

ward. From the apex of the V a furrow passes forward to the tip of the tongue, dividing the anterior portion laterally into two halves. The posterior portion is broken up into a series of folds taking about the same direction as the legs of the V.

Classification of Papillæ

The papillæ of the tongue have been described and classified more or less in detail since the middle of the seventeenth century. They can be grouped into four classes (Fig. 2), the circumvallate, the fungiform, the filiform, and the foliate papillæ, each group having certain distinctive characters. A fifth group is sometimes added and comprises the hemispherical, or simple, papillæ.

The circumvallate group comprise the largest and the most important papillæ. There are only from eight to twelve or sixteen of this type, and by their arrangement they form the V-shaped figure on the superior surface of the tongue, mentioned above, and which divides the anterior two-thirds from the posterior third of the tongue. These papillæ are found nowhere else. They rise only slightly above the surface of the tongue from the bottom of a pit or cup-shaped depression, giving the impression of a small mound surrounded by a ditch, whence the name, circum-

vallate. In a few cases more than one papilla rises from a single pit, but in most cases there is but one. The papilla itself has an average height of 2 millimeters, with a diameter at the top of 1.0 to 1.5 millimeters, and slightly less at the base. The cup-shaped depression averages about 1 to 1.5 millimeters in depth. The largest of these papillæ is that one forming the apex of the V-shaped figure and is called the foramen cæcum. The smallest are those found at the ends of the V.

The fungiform papillæ are so called on account of their resemblance to a toadstool. Each consists of a rather slender stalk capped by a relatively large, rounded head, about .8 to 1.0 millimeter in diameter. The whole papilla has an average height ranging from 1.0 to 1.5 millimeters. These are scattered very irregularly over the superior surface of the tongue, most of them being found on its anterior two-thirds. However, a few are found back of the circumvallate papillæ, but always very close to them. They are most numerous on the sides and the tip of the tongue, where they appear as bright red points upon the paler background of the tongue covering. The total number of this type has been estimated at from 150 to 200.

The third type, the filiform papillæ, cover the whole superior surface of the tongue and are so numerous that no estimation of their total num-

ber has been made. They are arranged in fairly regular lines running to each side from the middle line of the tongue and parallel to the lines formed by the circumvallate papillæ. They are believed to contain no sensory ends of taste and have only a mechanical function, if any, in connection with the taste mechanism. They are conical or cylindrical in form and vary in height from 1.5 to 2.5 millimeters. Sometimes these papillæ are covered with tiny secondary papillæ, which, however, are not apparent to the unaided eye.

The foliate papillæ consist of numerous small folds of the membranous covering of the tongue upon its sides and just in front of the line formed by the circumvallate papillæ. In these folds a large number of the taste bodies are imbedded. In certain animals, especially the rodents, these foliate papillæ form a very prominent part of the tongue, while in man they are no more prominent than the other forms.

The hemispherical, or simple, papillæ are found distributed over the whole tongue surface and form in many cases secondary papillæ upon the larger fungiform and circumvallate type.

The papillæ of these different types contain the largest number of the sensory ends of taste, or the taste bodies. These structures will be discussed in detail later. They are most numerous in the circumvallate papillæ, where one may find hun-

dreds imbedded in the side walls of one papilla. They are also found in the side walls of the depression from which the papilla rises. The fungiform type also contain these taste bodies imbedded in their side walls, although there are some in which none have been discovered. According to Nagel, the taste bodies have never been found in the filiform type. He ventures the opinion that the taste bodies are not necessary to produce taste sensations, with the result that the filiform papillæ may, after all, have something to do with taste sensations. There is always the possibility, first suggested about 1870, that the free nerve endings in the tongue surface may give rise to taste sensations.

The Determination of the Taste Areas

How shall the limits of the taste mechanism be determined? Two methods have been employed, and usually in conjunction. The first, or the anatomical method, consists in searching for the taste bodies (to be described later), and when they are found, to assume the possibility of taste sensations from the stimulation of that region. The second, or the physiological method, consists in applying stimuli of various sorts to different regions and finding whether taste sensations result. The limits of the taste mechanism, when determined by these two methods taken separately, do not

always agree. But there are cases in which only one or the other method taken alone can be applied. For instance, in the case of the embryo it is clear that only the anatomical method can be used, and in the case of the living human being only the physiological, or stimulation, method can be used.

The discrepancy between structure and function is possibly due, in part, to the presence of functionless taste bodies, useless landmarks in regions where in earlier stages of evolution the taste function may have been of vital importance. Such an explanation has been offered for the presence of taste buds upon the upper surface of the soft palate and upon the walls of the larynx and the vocal cords. But there are at least two other causes for the differences in limits of the taste sense as determined by the different experimenters,—careless and imperfect technic of experimentation and the great individual differences, according to age, race, and other conditions. Just on account of these individual differences it is impossible to define the limits of the taste sense which shall hold for all persons; one can only give averages and avoid the exceptions. Taking the average adult as tested by the two methods, one can say that the taste mechanism includes the following:

1. The superior, or upper, surface of the

tongue, with the exception of a patch just back of the tip. The size of this patch, which is insensitive to all taste stimuli, varies considerably with the kind of stimulus used and its intensity.

2. The sides and tip of the tongue. The under surface of the tongue of human beings is said to be insensitive to taste.

3. The soft palate, the uvula, and the tonsils, although the extent of these parts that is sensitive is subject to considerable variation. Kiesow and others fail to find the uvula sensitive at all.

4. The gums, the hard palate, and the mucous membrane of the lips are generally considered to be insensitive to taste. This absence of taste sensitiveness upon the hard palate, or roof of the mouth, is interesting when one considers its close connection with taste in popular speech. To "tickle the palate" with delicious food, to make food "palatable," are very common, though misleading, expressions. However, two very careful investigators have reported that the lining of the whole mouth cavity, including gums, the lining of the cheeks, the hard palate, and even the teeth, are sensitive to sour stimuli. Acetic acid of full strength was used as a stimulus in these experiments.

5. The epiglottis, parts of the larynx, and the vocal cords are sensitive to taste stimuli. Not

only have the taste bodies been discovered in these parts, but certain investigators, by applying solutions of bitter, sweet, etc., have been able to elicit the corresponding sensations from these parts. To these taste organs have been attributed the tastes aroused by certain vapors, such as chloroform, ether, etc.

6. The regio olfactoria, or the olfactory membrane, has been said to give rise to taste sensations, and the question has aroused much dispute. The evidence for thus attributing taste to the smell mechanism consists in the discovery in the regio olfactoria of bodies similar to taste bodies, and the further fact that breathing chloroform through the nose gives rise to a stinging sensation, followed by a sweet taste. Introspection seems to localize this taste in the nostrils. Nagel, however, denied the existence of this so-called "nasal taste" and performed a simple experiment to prove his contention. He finds that if one allows chloroform or ether vapor to be blown into his nostrils he will get a burning sensation, followed in the first case by a sweet taste and in the second by a bitter taste. But if while the vapor is entering the nostrils the person constantly utters a vowel sound, thus closing the passage between the nasal and mouth cavity, the sweet and bitter tastes will disappear, while the burning sensation remains. Nagel holds that this

shows that the taste sensations must be due to the stimulation of parts other than the nasal cavity. The same conclusion has been reached by the more careful researches of Nagel's students and others upon individuals whose nasal cavity and mouth cavity have been effectually separated either by growths or by artificial means.

One conclusion seems generally supported by the investigations of the distribution of taste, namely, that one cannot assert positively that wherever tastes have been definitely aroused there taste organs will be discoverable, or the converse of this, that wherever taste buds are found there taste sensations can always be aroused.

CHAPTER VI

Sensory Elements of the Taste Mechanism

Taste Buds and Their General Characteristics

Each sense mechanism has an arrangement more or less mechanical for modifying the stimulus, and another mechanism which transforms the stimulus into the nerve impulse, that message which is carried from sense organ to brain and there gives rise to consciousness. We know very little about the real nature of this nerve impulse transmitted from sense organ to brain, aside from its speed and a number of conditions affecting it. Some call it a chemical phenomenon, others an electrical phenomenon, and still others an electrochemical or physicochemical one. We know even less—in fact, nothing—about the change from nerve impulse to consciousness. But there are certain facts fairly well determined by microscopical examination of the sense organ about the nature of the mechanism which transforms the physical stimulus into a physiological one. In the preceding chapter the more mechanical features

of the taste mechanism have been reviewed, and in this one we will describe the transforming mechanism.

About 1865 it was found that the coverings of the tongue of mammals and later the lining of the mouth cavity contained peculiar little bodies, which, on account of their apparent shape and their connection with the sense of taste, were called taste beakers. Small fissures called taste pores were discovered among the most superficial epithelial cells of the mucous membrane of the tongue, and these were thought to lead into the small, flask-like chambers. Further study showed that the beakers were not in reality hollow, but consisted of closely packed groups of modified epithelial cells. They were then given the name of taste buds, on account of their resemblance to a bud with its tightly folded petals. These have been spoken of frequently in the preceding pages as sensory ends, and the regions in which they are found were enumerated.

Each taste bud is set rather deeply in the epithelial layer of the mucous membrane covering the sides of the papillæ and communicates with the surface only by the above-mentioned taste pore. Thus the taste bud is protected from direct stimulation by all substances except those which can gain access through the narrow opening. Occasionally taste buds are found which

lack this gustatory pore and communicate directly with the tongue surface. Such cases, however, are to be considered as exceptions. Likewise, twin taste buds are sometimes found, having a common base, but with peripheral ends distinct. These, too, are merely exceptions to the ordinary form and do not represent a type. The taste buds are globular in shape, measuring about 70 to 80 thousandths of a millimeter in length and about 50 thousandths of a millimeter in diameter. The taste pore averages only about 4 thousandths of a millimeter in diameter.

Supporting Cells, Gustatory Cells, and Nerve Filaments

A microscopical examination of the taste bud shows it to be composed of three structures. First, there is a series of modified epithelial cells closely packed side by side and forming a kind of hollow shell and determining the limits of the taste bud. These are sometimes called marginal, or supporting, cells. They are very long and narrow and their thickest part is that occupied by the relatively large nucleus. The extremities of the cells directed toward the taste pore are quite long and thin and are gathered together so as to form a small circular opening, the neck of the taste beaker or bud. Within this hollow globe thus formed some of the same kind

of cells are found, but it is almost entirely occupied by the second type of structure, the taste cell. These ordinarily range in number from 10 to 16 within any one bud, but sometimes as few as two or three have been found. These cells are longer and even more slender than the supporting cells and are very closely packed. The peripheral portion of the cell is very much elongated and ends in a hair-like filament which extends into the taste pore. All of these hair-like endings of the taste cells gather into a kind of brush within the taste pore. The centrally directed ends of these cells may have various forms—that is, there may be one long, thin branch or a number of branches, none of which, however, pass beyond the limits of the taste bud.

The third kind of structure found in a taste bud is perhaps the most important and consists of the fine branches of nerves which enter the taste bud at its base and twine around the taste cells. They do not actually grow into the cells, but pass through the taste bud and end very near to the taste pore in the form of small knobs or knots. Some of the fibrils, after reaching the peripheral end of the bud, turn back and really end in the more central portions of the bud.

Relations Among the Structures Within the Taste Bud

A great deal of experimental work has been done to determine the relations among these three parts of the taste bud. It was at one time thought that the supporting cells were modified epithelial cells and only served as a structural support for the taste cells, which were real nerve cells. According to this view, the taste cell is a neurone * which is directly affected by the stimulus and forms the first link in the chain of neurones connecting the surface of the body with the brain. They were thought to be analogous to the olfactory cells, which are true nerve cells. But a number of facts more recently determined tend to minimize the distinction between supporting cells and taste cells. For instance, when certain stains are employed for isolating the different structures it is found that these two sorts of cells stain alike, while the nerve fibrils within the buds stain differently from them. This is taken as good evidence that there is a difference in the composition of the taste cells and the nerve fibrils, and a likeness between the taste and the supporting cells. In fact, both types of cells are now considered to be modified epithelial cells and to be,

* Neurone is the name given to a nerve cell, and includes the cell body with its nucleus, and all of its branches.

in a sense, supporting cells. The former serve as supports for the very delicate nerve fibrils as they pass through the taste bud, and the latter, in addition to acting as supports in this way, also form the walls of the taste bud and thus protect the nerve fibrils from undue compression. According to this view, then, the nerve fibrils themselves are directly affected by the stimuli. Their knob-like endings, which are found so closely associated with the taste pore in most cases, lend support to this view.

One further sort of evidence tends to show the merely secondary function of these two types of cells in the taste bud. Certain portions of the tongue, e.g., parts of the tip and sides, which are extremely sensitive to taste stimuli, have very few taste buds, or none at all. But there is a multitude of free nerve endings in these parts which are thought to function without the aid of the supporting, or taste, cells. It will be recalled that in Chapter V it was necessary to conclude that there seemed to be no absolute dependence of taste sensations upon the presence of taste buds.

The Sensory Nerves of Taste

The taste sense differs from most of the other special senses in a number of respects, some of which have been mentioned in the preceding chapter. Still another striking difference is to be

found in the nerve supply for taste as compared with that of the senses of sight, hearing, and smell. In the latter group there is one nerve which carries the impulses from the sense organ to the brain. Thus, we have the optic nerve for vision, the auditory nerve for hearing, and the olfactory nerve for smell. In taste, however, no single cranial nerve can be called the nerve of taste or the gustatory nerve. There has always been a great deal of difference of opinion as to how the taste fibers are carried to the brain, no small part of which has been due to the seeming necessity for finding "a taste nerve." As early as 1823 evidence began to accumulate to show that more than one nerve must be involved. Other contributing factors to this confusion are, first, the use of experimentation upon animals—the conclusions from which have been considered valid for man as well as animals, an assumption which is not necessarily correct; and, second, the fact that there seem to be rather pronounced individual differences in the course taken by the fibers from taste bud to brain center. Three of the cranial nerves are now generally conceded to carry taste fibers: the lingual, which is a branch of the trigeminus, or fifth, nerve; the glossopharyngeal, or the ninth, nerve, and the vagus, or the tenth, nerve. The first two of these are more important for taste than the third. The

lingual carries the fibers from the anterior two-thirds of the tongue, the upper surface, and the sides of that portion of the tongue and the tip; the glossopharyngeal carries the fibers from the posterior third of the tongue, including the base of the tongue, the soft palate, and the papillæ foliatæ; the vagus carries fibers from the epiglottis and the larynx.

Although the above facts are well established, the more important question is, What is the origin of these fibers and how do they get into the nerve trunks in which they are found? To make this matter clear a word must be said about the general nature of sensory nerve paths. The connection between a sense organ and the brain consists of a series of separate links, which always remain distinct units. Each cell, or neurone, as one of these units is called, consists of a body, which contains the nucleus, and two sets of branches. In one set the branches are very short and numerous, called dendrites; in the other there is usually only one branch, called the axone, which is relatively long. A group of cell bodies is called a ganglion. In practically all sensory nerves these ganglia are situated outside of the central nervous system. The ganglia of the spinal nerves are located just outside of the spinal cord and are called simply spinal ganglia. The ganglia of the cranial nerves usually receive special names.

Thus, the ganglion for the great trigeminal, or fifth, nerve is called the gasserian ganglion. Of the two for the glossopharyngeal, or ninth, nerve that one of interest to us is called the petrosal ganglion. The vagus has two ganglia, an upper and a lower; the former, or jugular, ganglion is involved in the sense of taste.

From these ganglia the branches called the dendrites pass to the sense organ and are found twining around the taste cells in the taste buds. The other branches, the axones, pass into the brain stem and finally end in some brain center. The question, then, is, Do the taste fibers which are found in the lingual branch of the fifth nerve have their cell bodies in the gasserian ganglion, do those found in the ninth nerve have their cell bodies in the petrosal ganglion and those found in the tenth nerve have their cell bodies in the jugular ganglion? These are indeed difficult questions to answer. Reliance must be placed largely upon the results of surgical operations upon these nerves and ganglia, with their resulting effects upon the sense of taste. Earlier reports of surgical operations in which the gasserian ganglion was removed were that the taste sense on the tongue was completely destroyed, suggesting that all of the gustatory

fibers of the tongue had their origin in the gasserian ganglion. Later reports, however, were that only the taste sense of the anterior two-thirds of the tongue was destroyed by this operation, suggesting that the fibers found in the glossopharyngeal nerve were independent of the gasserian ganglion and really had their origin in the petrosal ganglion, these fibers getting into the lingual branch of the fifth nerve by a circuitous route.

The experiments of Cushing indicate, further, that operations with removal of the gasserian ganglion produced a dulling or complete loss of the sense of taste in the anterior two-thirds of the tongue, but this loss was followed later by complete recovery. The interpretation of these facts must be that the temporary effect upon the taste sense is only an incidental result of the operation and that the taste fibers for this part of the tongue originate in the geniculate ganglion, which is the ganglion for the facial, or the seventh, cranial nerve, and only get into the lingual branch of the fifth by way of the chorda tympani nerve. Consequently, the chorda tympani, a connecting link between the seventh and the lingual branch of the fifth, is extremely important for the taste sense, since it carries all of the fibers concerned in the taste function of the anterior two-thirds of the tongue. This nerve passes across the cavity

of the middle ear, and when stimulated mechanically, chemically, or electrically at this point is said to arouse taste sensations variously described as sour or metallic, sometimes as sweet and bitter.

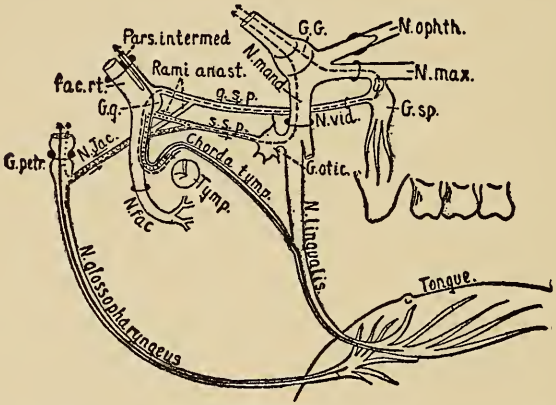

Fig. 3.—Diagram showing some of the various courses which have been advocated for the taste fibers in man. (Courtesy W. B. Saunders Company.)

Salt tastes alone have never been reported as resulting from such stimulation.

The taste fibers of the vagus seem to have their cells of origin in the jugular ganglion of that nerve. Thus, while taste fibers are found in the fifth, ninth, and tenth cranial nerves, it seems that the fibers really originate in the seventh, ninth, and tenth nerves. The accompanying figure (Fig. 3), after Cushing, will show

the facts about the distribution of the gustatory fibers.

The Cerebral Taste Centers

The first unit in the path connecting sense organ of taste and brain, represented by the neurones having their cell bodies in the ganglia described above, all end in the medulla oblongata, in the neighborhood of the fourth ventricle. These terminals, called the primary sensory nuclei for the seventh, ninth, and tenth nerves, are all included in the nucleus of the solitary bundle.

From these primary sensory nuclei a second series of conducting units begins, sending their fibers in two directions, downward into the spinal cord and upward toward the higher brain centers. Those fibers passing downward make connections in the medulla with the motor centers controlling mastication and swallowing and in the cord with the various motor centers. These connections make possible the reflex responses to taste stimuli, such as secretion of gastric and the other juices of the alimentary canal. Little is known about the course taken by the fibers which must carry the gustatory impulses from the primary sensory nuclei to the higher brain centers. It is quite likely that this second conduction unit is represented by fibers which mingle with those carrying

impulses from the sense organs of skin and muscles to the higher centers, and which are found in the median fillet, or the pathway in the brain stem for body sensations. These fibers end in the thalamus.* In the thalamus a third conducting unit begins and carries the impulses to a still higher center in the cortex of the cerebrum. Exactly what course the fibers take from the thalamus, or just where the cortical center for taste is, has not been definitely determined for human beings.

Indeed, less is known about the localization of the taste function in the cortex than about any of the other special senses. This is not due to lack of interest, for a large number of researches have been reported in this field. The reason is, rather, that there are certain difficulties in the way of its solution. First, the help to be got from physiological experiments upon animals is limited, because of the close relation between the senses of taste and smell, with the consequent uncertainty in interpreting behavior after surgical operations. And, second, since the exploration of the most accessible portions of the cortex has not revealed a taste center, it is probably located

*The thalamus is a center in the upper part of the brain stem, where connections are made between the cortex or outer layer of the brain proper and lower centers of the nervous system.

somewhere upon the ventral, or mesial, surfaces of the cerebrum, where experimental work is practically impossible. Clinical and physiological investigations have furnished conflicting results. A survey of recent work suggests that the most probable center for taste is in the hippocampal gyre near the anterior portion of the temporal lobe. No more definite localization is at present possible.

CHAPTER VII

Taste-Producing Substances

Adequate and Inadequate Stimuli

Ever since the doctrine of the specific energy of sensory nerves was presented by Müller, and since modified into the specific energy of sense organs or of cerebral centers, two sorts of stimuli for a sense organ have been spoken of. There are those called *adequate,*—for which the sense seems to be especially adapted,—and those called *inadequate,* to which the sensory mechanism is sensitive by virtue of its possession of a general irritability or sensitivity. It is a matter of common knowledge that one sees because his visual mechanism is stimulated by light, or rather by the vibrations of the luminiferous ether, and that this is the appropriate stimulus for visual sensations. But it is just as well known that if one receives a blow upon the head he will see "stars," or if he presses his finger upon his eyeball he will see patches of light. The sensations produced in this latter fashion are due to the mechanical stimulation of the sensitive visual mechanism, which responds with its specific kind of sensation. The

questions to be answered in this chapter are,— What is the kind of stimulus to which the taste mechanism is especially adapted? and, Are there other or inadequate stimuli which can produce taste sensations? In answering these questions it is well to keep in mind the biological function of the sense organ of taste. Situated as it is at the entrance of the alimentary canal it has been called the "eye of the stomach," whose duty it is to prevent the entrance into the body, by way of the mouth, of harmful substances. If this is so, the adequate stimulus for taste would be any kind of substance which might be taken for food.

Adequate Taste Stimuli

All substances may be classed either as *sapid,* tastable, or *insipid,* tasteless. And one of the main conditions for sapidity is solubility. A substance to be tasted must enter the mouth cavity as a fluid or else after being taken into it must be dissolved in the saliva. Thus, the adequate stimulus for the taste organ may be said to be a fluid. Recalling the structure and location of the sensory ends of the taste mechanism, it is at once inferred that only fluids can enter the taste pore and stimulate there the nerve endings of taste. It might then be assumed that all fluids should produce taste sensations. But all soluble substances are not sapid or tastable. Consequently,

other conditions of sapidity have been sought, among them being chemical constitution.

One of the most interesting attempts to solve the question of the conditions of sapidity is that which makes the only condition necessary, the contact of the substance with the nerve endings within the taste buds. Now, Graham pointed out that all tastable substances belong to the class of crystalloids, while tasteless substances belong to the colloids. It is known, too, that living membranes are permeable by certain solutions and not by others. Colloid membranes, of which all of the mucous membranes of the body are examples, are impervious to colloids in solution, while the passage of crystalloids in solution is rapid. Hence, no colloids, even those in solution, could actually reach the free nerve endings of the taste buds. As Nagel says, however, the truth of this assumption is not easy to settle, since it is very difficult to get pure colloids and to make sure that their chemical constitution is not modified by the saliva before contact with the taste nerves. Other possibilities will be discussed in the chapter dealing with the theories of the taste function. It will be sufficient here to say that the adequate stimulus to taste is a liquid, or a solid, or gas, which may be dissolved in the saliva. Gases such as chloroform vapor, carbonic acid gas, and the like, were at one time thought to act directly upon

the taste buds, but a safer view is that the gases are first dissolved in the saliva before acting on the taste mechanism. A few experiments have been reported in which the gases were said to have produced taste sensations when the mucous membrane was dry, but it is practically impossible to produce this condition, since the small glands of the tongue open directly into the fissures containing the taste buds and tend to keep the neighborhood of the taste pores in a moist state.

To say that the adequate stimulus for taste is a fluid is to give only an incomplete description of adequate stimuli. In the case of vision the adequate stimuli are ether vibrations; and the different visual sensations, reds, yellows, blues, etc., are attributed to ether vibrations of different rate.

And in the sense of hearing, the adequate stimulus of which consists of air vibrations, it is the different vibration rates that account for the qualitative or pitch differences in sound sensations. What characteristics of the stimulating fluids are responsible for the specific sensations sweet, sour, bitter, and salt? The answer to this question has been sought in the chemical constitution of the sapid substances. There is found to be a certain relation between chemical groups and the taste sensations they produce. Kiesow and others have pointed out that acids are sour; that

many chemical salts have a salt taste; that many carbohydrates taste sweet, and that most of the alkaloids are bitter. There are too many exceptions to these simple relations between chemical structure and sensation quality to have them serve as an answer to our question. There are chemical salts which taste sweet, there are acids which do not taste sour, and there are chemical substances whose tastes differ according to their concentration and even according to the part of the tongue which they affect.

Sternberg, who has made a very extensive study of the relation between chemical structure and sensation quality, has recognized the impossibility of finding a simple relation between chemical groups and sensation quality. His method of study consisted in cataloguing separately all those substances which taste sweet, sour, bitter, and salt, and then looking for similarities of structure within the same sensation group and differences among different groups. This is just the opposite of the customary procedure which was to take the chemical groups as a starting point and examine into the tastes aroused by them. He finds no difference in the molecule of a substance producing a sweet taste and a molecule of another substance producing a bitter taste, and finds similarities among the molecules of substances producing different tastes. He is forced to the con-

clusion that the tastes are due to the character of the intramolecular vibrations; that the taste mechanism is capable of responding to the relations among the atoms which have escaped the other senses, even when their keenness is increased by all sorts of artificial devices. Nagel, in reviewing this work of Sternberg, says that, in spite of the interesting facts which have been accumulated by him and others, very little has been contributed to the solution of the question of the stimulus for the different taste qualities.

Before dismissing the question of adequate stimuli one other set of phenomena ought to be mentioned. There are cases in which sapid substances dissolved in the blood produce taste sensations. In cases of diabetes, where sugar is present in the blood, a sweet taste is experienced in the absence of stimuli upon the tongue surface. Also, in cases of jaundice, where there is an excess of bile, a bitter sensation may be experienced. Here the stimuli affect either the taste nerves or the taste buds directly. There is no reason to think that the stimulation process differs in any other respect from the normal, except in the mode of access to the taste buds.

Inadequate Taste Stimuli

Our second question concerns the possibility of other stimuli to taste, or of inadequate stimuli.

Among these forms of stimulation three will be considered, namely, mechanical, thermal, and electrical. Are taste sensations produced by mechanical stimulation of the sense organ? Some of the older experimenters reported that tapping the tongue lightly or putting it under slight pressure aroused taste sensations of sour and bitter. But there does not seem to be good ground for such a conclusion. No doubt under poorly controlled conditions such mechanical stimuli might serve to force sapid substances already upon the tongue into the taste pores and thus stimulate the taste nerves. This, however, would be only an indirect effect of mechanical stimulation and not at all analogous to the visual sensations produced by mechanical stimulation of the eyeball.

It is rather interesting to note in this connection that mechanical stimulation of the chorda tympani nerve, which carries the impulses from the anterior two-thirds of the tongue, is said to produce taste sensations. In cases in which the ear-drum has been removed, stimulation of the nerve in the middle ear is said by some authorities to produce sweet and bitter sensations, and by others nothing but pricking sensations.

Thermal stimuli when applied to the tongue do not cause taste sensations, but only sensations of warmth and cold. Thermal stimuli, however, are recognized to have considerable influence upon

the effect of taste stimuli. Two cases are to be noted, that in which the sapid substance itself is either warm or cold and that in which the mouth has been subjected to warm or cold stimuli before the sapid substance is introduced into the mouth. The first condition has received the more attention on account of the importance of temperature in the supposed chemical reaction in the taste buds and the consequent possibility of interpreting the facts in favor of a chemical theory of taste. Both problems have been investigated by Kiesow and others, and the conclusions are conflicting. Some find that there is a certain optimum temperature for sapid bodies at which the taste sensations are best obtained, although there is no perfect agreement as to what this optimum temperature is. It varies from 55 to 120 degrees F. for different authors. At the optimum temperature the least quantity of the sapid substance is necessary to arouse a taste sensation, while a deviation from this temperature in either direction requires a stronger stimulus to arouse the same sort of a sensation. Kiesow, on the other hand, believes that the temperature of the sapid substance makes no difference, but only the temperature of the mouth previous to receiving the sapid substance. For instance, he holds that the sensitivity is just as acute when the temperature of the sapid substance is 32 degrees F. as when it is 100 degrees

F. But if the tongue is placed in water at 32 degrees F. for a few minutes it then becomes insensitive to sapid substances,—a kind of anesthesia results. He believes that the conflicting results obtained by the other investigators are merely the results of distraction of the attention. Whenever the temperature rises or falls beyond a certain point, then this temperature sensation becomes more impressive than the weaker taste sensation, and the taste sensation drops out of consciousness. It is a well-established fact, at any rate, that thermal stimuli cannot directly arouse taste sensations.

Taste sensations aroused by passing an electric current through the tongue were reported as early as the middle of the eighteenth century by Sulzer. Since that time a great number of experimental researches have accumulated in the attempt to answer the question whether an electric stimulus can directly arouse taste sensations, as it will produce sensations of light when it stimulates the eye. In all of this work there has been rather general agreement as to the character of the taste sensations present during electrical stimulation. Thus, when the anode (positive pole) comes into contact with the tongue the taste is said to be sour, while at the point where the cathode (negative pole) touches the tongue a bitter taste is reported. There is less general agreement upon the char-

acter of this cathode taste, however, than upon that of the anode taste, some describing it as burning, some as bitter, sweet, or alkaline.

The great differences of opinion do not concern the character of the taste aroused by the electric current so much as the real source of the stimulation of the taste buds. It was suggested by Humboldt about 1800 that the taste sensations were not caused directly by the electrical stimulation of the taste buds, but rather by certain sapid substances which were set free within the mouth by the action of the current on the saliva. It is known that fluid salts can be broken down by electrolysis in such a way that at the anode an acid reaction, and at the cathode an alkaline reaction, can be detected. These facts have lent support to the assumption that the saliva thus acted upon by the electric current produces tastable substances. An interesting experiment attributed to Volta about 1800 seemed for a time to refute the whole electrolysis theory. He used an alkaline fluid for the anode, into which the tip of the tongue was dipped. Even in this case the characteristic sour taste was still experienced. But this experiment, like all of the others which seem to refute the electrolysis theory of electric stimulation, neglects the fact that the electrolysis may occur within the taste bud itself, and hence could not be detected by any test of the tongue surface,

nor could the taste sensations thus produced be prevented by immersing the tongue in any kind of a solution, since this need not displace the fluids within the taste bud. The experience of both bitter and sweet tastes at the cathode, if these experiences are genuine, offers some difficulty for the electrolysis theory. The most that can be said is that it is quite likely that electrolysis takes place within the taste bud, but that, in addition to this, there may possibly be a certain direct action of the electrical stimulus upon the taste buds or their nerve endings.

From this review of the different ways in which the taste organ may be affected it appears that the evidence is not conclusive that mechanical, thermal, or electrical stimuli may arouse taste sensations. Chemical stimulation, which is usually included among the inadequate stimuli for the other senses, is the adequate stimulus for the taste mechanism.

CHAPTER VIII

Function of the Taste Mechanism

Function of Tongue and Salivary Glands

When sapid substances are taken into the mouth as solids, liquids, or gases they either become dissolved in the saliva or mixed with it. The glandular activity, with the resulting secretion of the saliva, as described in chapter V, may begin at the sight of the objects or may not begin until the substances have come into contact with the linings of the mouth cavity or tongue. The breaking down of the solid substances and their mixture with saliva is facilitated by chewing movements and by the movements of the tongue. When the substances have been transformed into the liquid state they move toward the back part of the mouth, from which the swallowing reflex movements will carry them into the gullet and stomach. In the course of this movement the fluids will come into contact with the tip, the superior surface, and sides of the tongue, and with portions of the mucous linings of the mouth.

And it is just in these regions that we find that the taste organs are located.

The uneven surface of the tongue, due to the presence of the papillæ, tends to retard the movement of the fluid substances and to give them time to affect the taste organs. It will be recalled that on the tip and the superior surface of the front part of the tongue there are few taste buds found, even where the papillæ of the filiform and fungiform type are numerous, but a tremendous number of free nerve endings are found close to the surface of the epithelial covering of the tongue. They can be affected by the fluids without passing through a gustatory pore into the taste bud. Now, it happens that the latent time of the sweet sense is very short compared with that for bitter. And since it is known that the bitter sensations are aroused especially by stimulating the circumvallate papillæ, which contain real taste buds, it seems quite probable that the free nerve endings in the forward part of the tongue are real sensory ends of taste and are directly affected by the fluid stimuli. It was at one time supposed that sweet tastes could not be aroused on this part of the tongue without the aid of tongue movements. Although this is no longer believed, it is, nevertheless, likely that tongue movements which would press its surfaces against neighboring parts of the mouth cavity would bring the sapid sub-

stances into contact with the free nerve endings, and that more quickly than in the absence of any movement.

As the fluids pass over the sides and superior surface of the tongue still farther back they meet the foliate and the circumvallate papillæ. The character of these papillæ is well adapted to retard the fluids in their passage and give ample time for stimulating the taste nerves. The former does this by holding the fluid in its long folds, or ditches, and the latter by collecting it in the circular ditches surrounding the papillæ proper. In these two types of papillæ real taste buds are found, with their taste pores leading from the surface into the interior of the taste bud. It is necessary, then, that the fluid be retained long enough to reach these hidden parts. As might be expected, there is a rather long latent time for the sensations aroused in these parts, namely, sour and bitter.

Tongue movements would be of service here, perhaps even more than in the forward portion of the tongue, in forcing the fluids more rapidly through the taste pore. But the tongue movements are said to be of use in still another way. The bases of the papillæ beneath the epithelial layer are supplied with a rich network of small veins. Now, tongue movements increase the flow of blood to the tongue and these veins become

congested with blood. Thus, the veins form a kind of erectile mechanism through which the papillæ become swollen, and at the same time the crevices in the epithelial tissue are opened wider, and easier access to the taste buds results. This hypothesis of the erectility of the papillæ is not generally accepted.

The devices in connection with the circumvallate and foliate papillæ, the circular and linear ditches, for retarding the fluid, may account for certain other characteristics of taste sensations, namely, the difference in duration of the taste sensations. Since the depressions and the taste pores become filled with the sapid substances, the taste sensations ought to last as long as the fluid remains, or until the taste organs become adapted to them, and thus interfere with the production of new and different sensations. But a corrective device for this defect has been assumed by certain investigators in the form of the numerous secretory glands found in the mucous membrane of this part of the tongue. These glands are said to pour their secretions through ducts into these depressions and flush them out, thus removing stimulating fluids and making way for new ones. This mechanism would prevent the confusion which would necessarily occur from the mixture of old and new sapid solutions in the depressions of these papillæ.

The Function of the Taste Buds

Real difficulties and differences of interpretation come when explanation of what takes place in the taste bud is attempted. Such questions as the following arise, none of which has received a perfectly definite answer. Theories of various sorts are all that can be offered in this connection:

1. Does the sapid substance affect the taste-bud cells, or only the nerve fibrils that twine around these cells?

2. If it affects these cells, does it affect the gustatory cells only, or both these and the supporting cells?

3. Does the sapid substance really enter the taste bud at all, or only affect the ends of the cells which form the so-called entrance to the bud?

4. Regardless of what portion of the taste bud is affected by the stimulus, what is the character of the effect produced? Is it mere contact or mechanical stimulation, or is it a chemical process which is set up?

5. Must different types of receiving structures, of whatever form they may be, be assumed for each type of elementary taste sensation?

The structural relations among the parts of the taste bud were discussed in the chapter on Sensory Elements. There it was concluded that the analogy between the sense of taste and that of

certain of the other senses, especially sight and smell, is not so close as it has seemed to be. It will be recalled that in these sensory mechanisms there are modified nerve structures, rods and cones in the eye, and the olfactory cells in the nose, which are affected directly by the stimuli, and in which a transformation of the stimulus takes place, with the resultant nerve impulse. This transformation accompanies a chemical change within these structures, hence vision and smell are called chemical senses. In the taste mechanism, also considered a chemical sense, it was natural to see in the gustatory cells of the taste bud structures with functions similar to that of the rods, cones, and olfactory cells. But the analogy between these types of structures breaks down because the gustatory cells do not have the characteristics of nerve tissue, as revealed especially by the use of differential stains. In fact, as has been said above, there seems to be no fundamental difference between supporting and taste cells. Two further facts seem to indicate that the supporting and gustatory cells take no primary part in the taste function. First, there is no more intimate connection between these cells and the nerve fibrils than that of contact, and the contact seems only incidental to the supporting function. The endings of the nerve fibrils are free from the cells. And, second, those free

nerve endings in the anterior portion of the tongue seem to arouse taste sensations without the intervention of any structures resembling the taste buds or their cells. Thus, the evidence to date leads to the conclusion that the nerve fibrils alone are the parts affected by the taste stimulus.

If this hypothesis be correct, is it necessary that the sapid substances should actually enter the taste bud, or only affect its peripheral end? Many of the nerve fibrils entering the taste bud pass through its whole length and end quite near the mouth of the gustatory pore. These might be stimulated without the entrance of the stimulus within the taste bud. But there are many of these fibrils which do not reach to the peripheral end of the bud, but stop far short of this point, and then there are others that reach the entrance of the taste pore but turn back and end in the characteristic knob-like formation within the taste bud. In order that these fibrils may be stimulated upon their ends the stimuli would have to enter the taste bud.

The answer to the fourth question is indeed the most difficult of all. What is the nature of this stimulation by which a fluid substance shall start an impulse along the nerve paths to the brain, which shall there produce sensation? About this last stage of the process nothing is known either about taste or any of the other senses. But very

well-developed theories exist to account for the transformation of the physical stimulus into physiological nerve impulse. For instance, in the case of vision, the stimulus for which consists of ether vibrations, these ether waves cause chemical changes in certain hypothetical substances within the rods and cones of the retina. It is this chemical change which creates the nerve impulse. In the case of hearing, for which the stimulus consists of air vibrations, these waves, being slightly modified by the more superficial portions of the auditory mechanism, finally cause vibrations of the basilar membrane, which, in turn, produces the impulse in the auditory nerve.

One of the earliest and simplest conceptions of the nature of the process in the taste organ was a mechanical theory proposed by Boyle, about 1675. He thought that the particles of various sapid substances differed in size and shape and that on account of these differences they produced different effects in their simple contact with the sensory ends of taste.

According to Graham, who announced his theory in 1889, sapidity of substances depends on their chemical constitution, colloids being generally insipid and crystalloids being sapid, hence this has been known as a chemical theory. This difference of chemical structure, discussed on page 94, was made to account for the contact, or the

lack of it, between the substances and the sensory ends, but does not account for the effect produced upon the sensory ends by the substances reaching them.

Sir William Ramsay prepared an explanation quite analogous to the theories of color vision and called it a dynamic theory. According to him, the real stimulus to the taste organs is molecular vibration, the different taste sensations being due to stimulation by different rates of molecular movement. Just as in the case of the luminiferous ether or of the air there is quite a range of molecular vibration rates, from exceedingly slow to exceedingly rapid. And, just as in the case of vision and hearing, so is the taste mechanism tuned to respond to only the middle range of these molecular vibration rates. Substances may then be insipid, either because their molecular movements are too slow or too fast to affect the receiving mechanism. In vision we have the analogous case of the infra-red and the ultra-violet rays not producing visual sensations, because they are beyond the range of sensitivity of the eye. Yet the effect of these rays can be recorded by other means. The rate of molecular movement depends on the weight of the molecule, so that very heavy or very light molecules would not produce taste sensations.

About the same time Richet and Gley per-

formed a series of experiments which seemed to show that the molecular weight of the substance was an important factor in producing taste sensations. They found that the intensity of the effect produced by different salts was in proportion to their molecular weight; that if account was taken of the different molecular weights of the salts used as stimuli the threshold stimulus would be the same for all of the salts. But if solutions were prepared according to the absolute weight of the salts these threshold stimuli appeared to be quite different for the different salts. Later experiments have shown that the same relation does not hold for sour-producing substances, certain sours of very small molecular weight having the sourest taste.

Sternberg, whose work was mentioned in chapter VII, recognized only two elementary taste sensations, sweet and bitter, and he found no differences in the molecule of substances producing these two sensations. He concludes that it is the intramolecular vibrations that form the real taste stimuli. By transferring the seat of the activity from molecular vibration to intramolecular vibration the whole matter becomes more difficult of solution and verification. Still, the modification of the theory of Ramsay, made necessary by the work of Sternberg, would leave its essentials, namely, that vibrations of some sort form

the stimulus and that the sense organ of taste is tuned to receive only a limited range of vibration rates.

Granting that a dynamic theory as outlined above, with possible modifications to meet new discoveries, is correct, still another question requires an answer. In the visual organ affected by ether vibrations of different rates every theory assumes certain parts of the mechanism sensitized especially to certain vibration rates. To take the theory of Hering, for example, there are three photochemical substances, one decomposed by a relatively slow vibration rate, another by a more rapid vibration rate, and so on. And in the auditory mechanism there is the *basilar membrane,* capable of vibration in parts in sympathy with different rates of vibration of the air. The answer to this question concerning the taste sense is peculiarly difficult, in that it is impossible to stimulate individual taste buds, and even difficult to stimulate a single papilla, which may contain many buds. And then it must be further borne in mind that each bud contains many nerve endings, so that what is stimulated in experimental work is really a very complex portion of the sense organ.

As mentioned in another connection, certain papillæ when stimulated with various substances respond to but one, e.g., sweet, sour, bitter, or

salt, while others respond to two or three stimuli. Further, it is well known that certain portions of the tongue when stimulated produce a predominance of certain kinds of taste sensations. On the other hand, an examination of the taste buds or of the nerve endings within the taste buds shows no differences among them. Still, in this respect taste does not differ from sight. The cones of the retina, which are sensory ends of vision, show no differences in structure, and it is generally believed that all of the elementary sensations can be produced by the stimulation of one single cone. If it be true that the nerve fibrils in the taste buds themselves receive the stimulus, then any specific characteristics of the receiving mechanism would have to be looked for in these nerve endings.

Oehrwall has accounted for the facts of the specific sensitivity of different parts of the tongue and of different individual papillæ mentioned above by the assumption that each taste bud has a specific function and that certain papillæ of the tongue have buds all of one sort, other of two sorts, and so on. Nagel prefers to modify this view to the extent that each taste bud is capable of arousing every elementary sensation, but is adapted to respond best and easiest to a certain specific stimulus with a certain elementary sensation. This view is analogous to that of the visual

photochemical substances which, according to the Helmholtz theory, were each sensitive to all wave lengths of light, but not equally.

The previous review of theories does not consider the possibility of the specific energy of brain centers, rather than of the peripheral sense mechanism—that is, the possibility that the sensation qualities, sweet, sour, etc., may be due to structural characteristics of brain centers, rather than of sense organs. This is a question which is unsolved for other senses and consequently is not peculiar to taste. The present tendency seems to be toward attributing the different sensation qualities to the sensitivity of the sense organ, or else to divide it between brain center and sense organ. The following facts are considered as indirect evidence of the specific energy of the sensory ends of taste: (1) The distribution of taste sensitivity over the tongue. (2) The effect of certain drugs, e.g., cocaine, which destroys the taste sensations one at a time. This suggests that the sensory ends that have to do with the different sensations are differently affected by the drug. (3) The fact that the same substance as it passes over the surface of the tongue arouses different sensations, e.g., sodium sulphate, which is sweet on the tip and bitter on the back of the tongue.

CHAPTER IX

The Development of Taste in the Individual

Development Before Birth

The structures concerned with the taste sensations develop early in the life of the human embryo. As early as the twelfth day the rapid development of the head end of the embryo causes an infolding of the *ectoderm* (outer layer of the embryo), which later forms the mouth and nasal cavities. And about the twelfth week the mouth structure is fairly complete. It has at this stage become separated from the nasal cavity through the growth of the hard and soft palate.

At the twelfth week the tongue is also fairly well developed as a single organ, although originating from three or four separate parts which grow together. The anterior two-thirds of the tongue—that is, all of that portion back to and including the rows of circumvallate papillæ of the adult tongue,—grows from the floor of the original mouth structure. It is in this portion alone that papillæ are to be found. At the end of the

fourth week the circumvallate papillæ begin to appear and at the twelfth week the fungiform and filiform papillæ begin to appear.

About the fifth month there begins a multiplication of the cells in the germinative layer of the epithelium covering the tongue, which marks the beginning of the taste buds. At the eighth month the development has advanced so far that the gustatory cells can be distinguished from the supporting cells, and the whole taste bud has separated itself somewhat from the surrounding tissue. The nerve fibrils found in the fully developed taste bud come into connection with the gustatory cells very early in their history—in fact, the presence of the fibrils is considered by some authorities as the stimulus to modification of the epithelial cells into those special forms and the consequent formation of the taste buds.

At birth the most essential parts of the taste mechanism seem to be fully developed and able to function. The taste buds and the taste pores by which they communicate with the tongue surface have the same structure as in the adult. The papillæ, however, according to Stahr, have not attained the adult form. From an examination of the tongues of a large number of newborn babies he reports that the foliate and the circumvallate papillæ are not complete, the depression surrounding the latter being broken in places and

one papilla not clearly distinguished from others. The fungiform type, too, does not at this stage resemble a toadstool, as it does in the adult, but they are more like very large filiform papillæ. Microscopical examination shows both of these types of papillæ to carry their taste buds on the top, rather than far down upon their sides. In no case did Stahr find a fungiform papilla without one or more taste buds.

The distribution of the taste buds over the surface of the mouth cavity of the fetus and the newborn, as determined by histological examination and experiment, is very extensive, as compared with the adult. The presence of taste buds and of taste sensitivity has been reported upon the arches of the palate, over the whole dorsal surface of the tongue, and the inside of the cheeks. Buds are especially numerous upon the tip of the tongue.

Development of Taste in Infancy and Childhood

After birth certain changes occur in the taste organs. During the whole period of lactation the tip of the tongue remains especially sensitive to sweet stimuli, a valuable condition for the promotion of the food-taking reactions in the infant. During this period also the whole superior surface of the tongue remains sensitive to taste stimuli, but with increasing age there appears a

region of insensitivity just back of the sensitive tip. At the same time there is said to be an increasing sensitivity upon the edges of the tongue.

The insensitive zone differs in extent for the different elementary tastes, but is fairly large for all. These progressive changes in sensitivity have been explained as the result of the appearance of the teeth and their importance in the bodily economy. While the individual lacks teeth and subsists on a milk diet the process of nourishment is best accomplished by having the food pass directly back over the superior surface of the tongue until it reaches a point where the swallowing reflexes are set up. However, after the teeth appear and mastication of food is necessary, then it is better that the food should pass from the tip of the tongue to either side, where it will come between the teeth! Thus, seeking the maximum taste sensation from the food is equivalent to placing it in a position to be thoroughly masticated. Further, the presence of food, and especially sour food, upon the sides of the tongue forms the stimulus to the flow of saliva, a necessary factor in preparing the food to be swallowed and digested. Now, if the superior surface of the tongue were highly sensitive to taste stimuli there would be a tendency to hold the substances upon that part in order to prolong the pleasure, thus retarding the proper mastication of the food.

A simpler explanation of the decreasing sensitivity of the upper surface of the tongue and the increasing sensitivity of the sides is the fact that, after the teeth appear, chewing would tend to collect the dissolved food substances at the sides of the tongue, rather than upon its dorsal surface, hence the greater importance of the taste buds upon the sides of the tongue.

It is difficult to see why the inside of the cheeks should be sensitive to taste stimuli in young children and why this sensitivity should be lost in the adult. Titchener has suggested that its presence in children may account for their desire to take large mouthfuls of food, thereby getting maximum taste sensation.

Whatever the biological interpretation of these changes may be, certain structural changes have been noted which seem to account in part, at least, for the changed sensitivity. The circumvallate and foliate papillæ become complete during the first few months and the taste buds, instead of being located upon the top of the papillæ, are now found rather low down upon their sides. The change in the fungiform type is more pronounced. These, more or less conical in shape at first, begin to acquire an enlarged head (by the growth of secondary papillæ, according to Stahr). Not only this, but the taste buds in all of them are now found to have moved from

the top to the sides of the papillæ, and many of the buds have disappeared altogether, some of the papillæ apparently losing all taste function. There are various opinions as to how the buds change their position or are lost, but none of these are well enough established to need description.

Thus, by the completion of growth in the circumvallate and the foliate papillæ and by the degeneration of the fungiform (loss of taste buds) the region of greatest sensitivity is transferred from the tip to the sides and back part of the tongue, while the zone just back of the tip becomes entirely taste blind.

Taste in the Adult

The most striking characteristics of taste in the adult as compared with that of the child, then, is what appears to be a gradual reduction in the extent of distribution of taste sensitivity and a shifting of the region of the greatest sensitivity. No doubt there are other changes, e.g., a general reduction in delicacy of taste analogous to the sort of change which is noted in the other senses as age advances. In extreme old age such a condition is quite pronounced. In hearing, for example, there is not only a dulling sensitivity but a shortening of the range of audible pitches, especially in the region

of the higher pitches. So, on the tip of the tongue, sensitivity may be very much reduced or disappear entirely. These changes in taste are not commonly brought to one's attention as are those of sight and hearing, because they affect our life less vitally. But there is little doubt that careful tests would reveal them.

Structural and Functional Differences Among Individuals

It has been suggested that individuals differ considerably in the distribution and function of their taste mechanism. In the search for general laws these variations within the limit of normality have been looked upon as troublesome exceptions and not of much interest. And these differences are no doubt responsible for the lack of agreement among investigators on many points. For instance, there are persons whose sensitivity on the tip of the tongue is so poor that sweet tastes can be aroused only with the aid of tongue movements. This and other similar cases have given cause for the belief in the necessity of tongue movements for arousing all taste sensations. Some investigators have found the tonsils and the uvula sensitive, while others have found them insensitive. When one finds such conflicting statements from men like Nagel and Kiesow, individual dif-

ferences seem a plausible explanation. No special studies have been made of these individual differences. Consequently, about all that one can say is that the distribution of the taste buds in different people is subject to considerable variation and that on this account one cannot definitely mark out the limits of their distribution which shall hold for all persons. The same is true of the distribution of sensitivity to specific taste stimuli, sweet, sour, bitter, and salt substances. Such vague statements as are usually made, namely, that sweet is best tasted upon the tip of the tongue, sour upon the sides, bitter upon the back, and salt over nearly the whole tongue, are true, but when one attempts to assign definite limits to these regions then great individual differences appear.

Individual Differences Due to Pathological Changes

More extreme variations in taste are frequent as an accompaniment of disease or congenital malformation of the cerebrum. These variations may be in the nature of absence of sensitiveness, dull (hypo) sensitivity, or very high (hyper) sensitivity. Only one case, so far as we have found, has been reported of congenital taste blindness, either for all taste sensations or for one or two of them, such as would correspond to hereditary

color blindness of the various sorts. The apparent absence of taste in certain idiots is not a form of taste blindness to be compared with color blindness. Such persons will eat sulphate of quinine with as much enjoyment as sweet food, but so will they try to eat wood or stones or paper. Nor are the cases, which are more or less common, of dulled taste sensitiveness as a result of cerebral malformation to be compared with real color blindness, which, as far as is known, at least, depends upon no such cerebral abnormality.

There are cases of acquired taste blindness, either general or for special qualities, which resemble in general character acquired color blindness. In both senses the blindness results from pathological changes in the sensory mechanism, either in the sense organ, its centers within the brain, or its connecting nerve trunks. The nature of the sensory defect depends upon the extent of the pathological change and its location. Thus, there may be general taste blindness if both of the cerebral centers are involved, a defect on only one side of the tongue if one cerebral hemisphere is involved. And if the disturbance is in the nerve trunks, only the anterior two-thirds of the tongue may be affected, or only its posterior third. Again, if the lesion is in the sense organ itself, one or more specific taste qualities only may be

lost, or all qualities for a very small portion of the tongue. These latter cases are of much importance in developing an adequate theory of taste function. Nagel describes a case in which all sorts of taste stimuli produced only a sensation of salt on one side of the tongue, while on the other side taste was normal. This peculiar condition was followed by a total loss of sensitivity on the affected side.

Epileptics are said to show taste abnormalities of varying character after an attack, and lasting for hours in some cases. There is usually a loss or dulling of the sense, most prominent for salt and least noticeable for bitter. Such conditions are not peculiar to the taste sense, for there is usually a disturbance of the other special senses also after an epileptic attack.

All sorts of taste abnormalities are found in hysteria, but little is known of their underlying causes in the taste mechanism. There may be either hyper- or hyposensitivity, although the latter is more common; and both sides of the tongue or only one side may be affected, or even only a small portion of the tongue may be involved. Here, too, the taste abnormalities are accompanied by disturbances of the other senses.

Criminals, especially those recognized as degenerate, show taste abnormalities, usually extreme dullness of taste, along with the same sort

of defect in the other senses. Attempts have been made to find a positive correlation between keenness of taste and number of stigmata of degeneration, but with no success.

Any condition affecting the mucous lining of the mouth cavity may be expected to modify taste sensitivity. For instance, burning the tongue with a hot drink will destroy taste for a time. Tumors and abnormal thickening of the epithelium of the tongue will likewise disturb the taste function. These effects are clearly due to a direct action upon the taste buds or the gustatory pores, and may be local or general in character. Under this head might be mentioned the effects of drugs applied to the tongue surface, but they have been discussed elsewhere. Hallucinations of taste likewise, of which there are a great variety, have been described in another connection.

Racial Differences in the Structure and Function of the Taste Organs

A number of races, e.g., Negroes, Japanese, Europeans, etc., have been studied to determine differences in the taste mechanism, but little of significance has been found. The number of papillæ upon the tongue is just about the same in every case. The slight differences of size and arrangement of the papillæ, especially the circum-

vallate type, are not such as to be of much importance from the functional point of view. The variation in these respects is so large within any one racial group that there is little likelihood of finding significant racial differences.

CHAPTER X

Evolution of Taste

Sensitivity of the Unicellular Organisms

The study of the sense organ of taste in adult human beings consists of an examination of the taste sensations resulting from controlled stimulation of limited parts, supported by the microscopical examination of the structures found in the regions in which these taste sensations can be aroused. The relation of cause and effect is then assumed. Neither method taken alone will suffice, as there always remains the possibility of function in the absence of definitely recognized taste structures and also the possibility of the presence of functionless structures. The difficulties and uncertainties arising in this combined study of structure and function have been discussed in earlier chapters.

But if the determination of the taste organs and their localization offers difficulties in the adult human being, these are multiplied many times when the study is carried to the lower animals. The method of stimulation is greatly limited, to

what extent depending upon the kind of animal studied, because the results of the application of stimuli must be interpreted from the forms of behavior exceedingly crude, compared with the language behavior of man. This handicap in the study of taste is great, as compared with sight and hearing, at least, on account of the extremely close relation between the taste and smell organs in position and in the nature of their appropriate stimuli. In case of certain of the lower animals the assumption of distinct states of consciousness corresponding to our experiences of taste and smell is unwarranted, as is even the assumption of any consciousness at all.

The study of taste structures reduces itself largely to the search for sense organs resembling those of man, and in the same neighborhood as they are found in man. Here again the difficulty is especially great in taste, because the taste organs even in man are not very highly differentiated from other structures, and the really essential part of the organ is not definitely known. (See Chapter VI.) In the search for taste in lower animals one must rely much upon the expectation of finding the taste mechanism in the mouth or its immediate neighborhood. Structures found here and not known to function otherwise are likely to be looked upon as taste organs. These assumptions from location are then tested

by stimulation of the parts with sapid substances and looking for characteristic responses, and further by extirpating these organs and noting the effect upon behavior. Other criteria of sensitivity, which can be used especially in the study of sight and hearing, such as rate of fatigue, reaction time to stimulation, and the like, are of little use on account of the above-mentioned close relation between taste and smell.

When looked at from the evolutionary point of view, all of the senses are seen to have developed through modification of the *sensitivity* of a single structure, the cell, with its additional properties of conductivity and motility. In the simplest living organisms, for instance, one finds sensitivity to consist in the irritability common to all living cells, and the sense organ to be represented by the whole cell. Still, the amœba, one of these unicellular organisms, reacts differently to the contact of food substances and to purely mechanical stimulation. And the white corpuscles of the blood in the human body are said to adjust their behavior according to the chemical composition of their surroundings. So, even in this earliest stage of evolution, before any differentiation of structure appears, one sees a reaction analogous to the taste reactions of the higher animals.

"The Chemical Sense"

In the simpler multicellular organisms, which develop by cell division and multiplication from a single cell, the cells differ from the original type and from each other in position, structure, and function. In the course of growth the organism originally spherical in shape becomes modified by irregular growth of cells, producing folds and prominences. Cells are crowded out of shape; some lie at the base of a depression protected from stimulation; others occupy positions which make them especially liable to be acted upon by such stimuli. In the course of these modifications some of the cells become especially adapted for receiving impressions, others for conducting or transmitting these impressions to various parts of the organism, others for producing movements of the organism. It is with the first type of cell that we are concerned, the receptor mechanisms. They are in the simpler organisms, adapted to receive two sorts of stimulation, mechanical and chemical. In fact, through the whole series of multicellular organisms such reactions to mechanical and chemical stimuli have been noted more or less definitely, although special sense organ structures have in many cases not been discovered. This is especially true for the reactions to chemical substances. It is customary to speak

of the "chemical sense," to signify these responses to chemical substances, without any attempt to differentiate between smell and taste. Obviously, in the case of organisms which live in a fluid environment, this chemical sense might be called taste, since it would correspond in a way to that sense in man, for which the adequate stimulus is a fluid. But since it is a "distance receptor," in that objects at a distance can produce responses, probably by diffusion of substances in the fluid, it might also be looked upon as more nearly resembling the smell sense. In most cases structure offers no help in settling the matter.

In the medusa, or jellyfish, one of the earliest forms in which a nervous system and sense organs are found, the tentacles are especially sensitive to chemical stimuli, much less so to mechanical stimuli. To the former they respond by shortening and twisting themselves about the object. As for sense organs in these parts, there are small club-shaped papillæ in the neighborhood of the tentacles, differing somewhat in character in the different species. These papillæ contain a narrow canal lined with thick cylindrical cells. As far as both structure and function are concerned, they may be considered either as taste or smell organs.

In the flat worms, where a nervous system with

a rudimentary brain is found, the reaction to chemical stimulation is not clear. This organism has specialized responses, among which is a movement toward food placed near it. But whether this is a reaction to chemical stimuli alone or combined with mechanical is not known. No taste organs have been found. Pits or depressions found on the lateral surface of the anterior end of the worm, and supplied with nerves from the brain, have been regarded as olfactory rather than as taste organs.

In the annelid group, of which the earthworm may be taken as an example, there are well-defined chemical reactions, which more nearly resemble taste reactions than the cases previously mentioned. Here a positive reaction to food substances seems to occur only when these substances come into contact with the body. For instance, the characteristic burrowing reactions of the earthworm are not aroused by placing filter paper soaked in manure near them, but only when the paper is actually in contact with the body. Negative reactions, however, to strong chemical stimulation may take place without contact. Attempts have been made by Parker and Metcalf to show specialized taste reactions to different chemical substances by measuring the latent time in the responses to various substances brought into contact with the body. From such evidence as this it

would appear that earthworms have specialized reactions to the chlorides of sodium, potassium, lithium, and ammonium, which are indistinguishable to the human taste sense, with their common salt taste. These results are interpreted as indicating qualitatively different effects of the stimuli. In these organisms it has been possible to discover taste organs, distinct from the olfactory organs. They are described as cup-shaped organs, which may be either depressions or prominences. They occur in large numbers and are widely scattered over the body. They are said, however, to be especially numerous at the edges of the mouth and within the mouth cavity.

The crustacea, among which are the crabs and the lobsters, characterized by their hard shell-like covering, show certain specific reactions to chemical substances when these come into contact with the parts of the body near the mouth. Reactions to chemical stimuli applied to any part of the body of the crayfish have been reported by Bell. The positive reactions were such as to bring the substance toward the mouth and the negative reactions such as to remove the substance. Responses to such substances at a distance are uncertain. But it is difficult to differentiate between possible smell and taste reactions. The sense organs in these organisms are usually located upon the antennæ, or feelers, in the neigh-

borhood of the mouth. Here there is a different kind of response to chemical and mechanical stimulation. No structures with a specific taste function have been described, although smell and tactile organs have been localized.

In the organisms described above, the chemical, or, more specifically, the taste, sense is a food sense,—edible and inedible substances causing reactions of different character. The reactions to stimuli within the edible group, however, show no variation. In the insects, especially the ants, bees, wasps, etc., there seem to be qualitative differences in the effect produced by chemical substances. It is by means of this chemical sense that bees and ants are able to find food at a distance, to return to their homes under all sorts of adverse conditions, and to distinguish nest mates from enemy intruders. But, since these are all reactions to stimuli at a distance, they must be attributed to the smell sense, rather than to the taste sense. But in the case of these organisms a sharp distinction between smell and taste seems possible. Forel and others have offered honey mixed with strychnine to ants, who seized it greedily, indicating an olfactory sensibility. But immediately after the honey had touched the mouth parts, avoiding reactions, such as to remove the substance, followed, indicating sensitiveness to the bitter substance. Wasps and bees

will make the same sort of responses if distasteful substances which are inodorous are mixed with pleasant, odorous substances. The sensitivity to tastes varies considerably in different insects, being very great in bees and ants. From such experiments as the above it has been concluded that the smell organs are located on the antennæ and that the taste organs are located on the lips and in the mouth. Microscopical examination shows that in all insects the tongue and inside of the mouth are covered with minute pits, or depressions. In each pit there is a minute hair, or rod. Some observers say that this rod is hollow and perforated at the end, thus communicating with the nerve which ends at its base. Other observers say that there is no perforation upon the end of the hair. However this may be, there seems to be no doubt that these are the taste organs. The same type of structure has been reported on the proboscis of the bumblebee, the hive bee, and the common fly. They are said to resemble a hollow hair, the channel communicating with a nerve fiber at its base. In the insects, then, we find the earliest definitely specialized taste mechanism.

Chemical Sense in Fishes

In the fishes, again, the distinction between the senses of smell and taste becomes more difficult,

on account of their fluid environment. But, disregarding the distinction between smell and taste, the general chemical sense plays a very important part in the life of the fish. Now, some observers have included all of this sensitivity to chemical substances within the sense of smell, while others have attributed a part of it to a taste mechanism. As representative of the latter, Herrick's conclusions are of interest: "In fishes the gustatory system is much more extensively developed than in mammals, especially the vagal part which supplies the taste buds in the gill region. In some species of fishes, moreover, taste buds appear in great numbers on the outer skin, and these are in all cases innervated from the seventh cranial nerve. In the common horned-pouts, or catfishes, and in the carps and suckers these cutaneous taste buds are distributed over practically the entire body surface, and especially on the barblets. . . . These sense organs and their nerves are entirely independent of those of the lateral line system, and of the ordinary tactual system, though the gustatory and tactual systems have been shown experimentally to coöperate in the selection of food."

Herrick determined by experiment that the sense organs thus generally distributed over the body of the catfish really had a taste function. Food placed at a distance from the fish produces

only restless movements, indicating that the eyes do not direct them to it. But if food comes into contact with the mouth parts, or, in fact, any part of the body, it is immediately seized. To show that this reaction is not alone due to tactual stimulation, the tactual organs were first stimulated with cotton wool, which produced the characteristic seizing reaction. But after stimulation was continued for a while reaction no longer followed. If at this point the cotton wool be soaked with meat juice, the seizing reaction is again set up. Adaptation to tactual stimulation has taken place, leaving the taste organs to function alone. To show further that the responses did not depend on olfactory stimulation, the olfactory nerves of certain fishes were cut. When the experiment was performed, after recovery from the operation the responses were the same as in normal fish.

The experiments of Parker show further that the mouth and external surface of the body of certain fishes are sensitive to sour, salt, and alkaline solutions. Sheldon obtained about the same results. The external skin covering is not sensitive to sugars. The tongue of fishes presents a smooth, gray, dorsal surface, devoid of elevations or papillæ, which characterize the tongues of many other organisms. Nor is it a mobile organ in comparison with other species. On the whole,

the tongue itself seems little adapted for arousing taste sensations.

The system of "lateral line" organs of fishes have at times been thought to be concerned with the chemical sense. This is probably not the case, although their exact function is a question still under dispute.

In a general way, the taste buds, or sense organs of taste of fishes, resemble those of the human being. They are either flask- or cup-shaped, and are composed of two types of cells, called supporting cells and taste cells. The latter cells end peripherally in a hair or bristle, just as the same kind of cell in the human taste bud.

Land-Dwelling Animals

There seems to be no experimental evidence for a specific sense of taste in amphibia, or reptiles. But sense organ structures have been described upon the tongue and soft palate of the frog, where they are said to occur in hundreds. They are disc-shaped structures, made up of several kinds of cells, which correspond to the real taste cells and supporting cells of the human sense organ. The taste cells end peripherally in several hairs or bristles, and at their central end make connection with nerve fibers. In the reptile group there is neither experimental evidence of taste sensitivity nor anatomical evidence of the

presence of taste corpuscles on the tongue or in the mouth cavity.

The experimental evidence for the taste sense in birds is slight. It certainly is greatly overshadowed by the keen senses of sight and hearing. Birds seem to represent one case, however, in which taste is more important than smell. Taste sensitivity for different chemical substances, in the case of young chickens, at least, seems clear from certain studies of instinct and learning, in which they accept certain kinds of food and reject others after tasting them. In considering the sense of taste in birds it must be remembered that most of them swallow their food without chewing it or without having it reduced to liquid form through mixture with saliva. The tongue, which varies in character considerably in different types of birds, is in most cases covered with a horny coat. Numerous hard papillæ are found upon its surface. Microscopical examination of these papillæ shows nothing which can correspond to taste buds or to gustatory cells. The parrot is said to form an exception to most birds, in that it has a relatively soft and fleshy tongue, with numerous papillæ, and also in that it chews its food.

In the duck, which has a large tongue, there are certain portions which lack the hard covering common to birds' tongues. Here, in addition to

a large number of tactile corpuscles, there are groups of cells which resemble somewhat true taste corpuscles. The peripheral ends of their cells reach the surface of the mucous covering of the tongue. The cells do not end in the bristle, or hair-like, formation, as those of the human taste cells, but in a pointed elongation of the protoplasm. Experimental evidence of the function of these structures is lacking.

Taste sensitivity and the structure of the taste organs differ greatly in the mammals, but there seem to be two characteristics in common, namely, the localization of the taste corpuscles within the mouth and the importance of the tongue in arousing taste sensations. The character of the mucous lining of the mouth also shows great variation in the number of papillæ and the taste buds which they contain. The number of papillæ varies from two or three in the marsupials and four in the elephant to an extremely large number in rodents, e.g., the rat. The papillæ are in general quite similar to the three most common forms in the human taste organs, the circumvallate, the fungiform, and the filiform, and have about the same location in relation to each other. The greatest difference is in the prominence of the fourth type, the foliate papillæ in certain mammals, as compared with man. These are seen best in the rabbit, as folds directed downward and forward on

the sides of the tongue in its posterior portion. They have been considered to result from the great number of papillæ which throw the mucus into folds. Each foliate papilla is composed of a number of parallel ridges, each ridge in turn being composed of papillæ of the fungiform type. Between the ridges there are narrow ditches. It is in the side walls of these that the taste corpuscles are found in greatest numbers. Thus, these ditches are analogous, in function at least, to those of the circumvallate papillæ. Their origin, however, seems to be different from that of the circumvallate. In the monkey one finds less prominent folds on the sides of the tongue, rich in taste corpuscles, which represent the foliate papillæ.

The taste corpuscles themselves have about the same characteristics in all mammals as in man. There are differences in size, to be sure, but their structure is the same, and the supporting cells, gustatory cells, and nerve fibers are present in them all.

This survey of taste in the animal kingdom suggests the conclusion that the taste organs represent a modification of the original skin sensitivity or touch sense, and surely a slight modification when compared with the senses of sight and hearing. A certain resemblance has been remarked by Wundt and others between the touch

corpuscles and the gustatory corpuscles. His interpretation is that the whole body was originally endowed with the touch sense, while certain parts being affected continually by specific sorts of stimuli, became adapted to them by undergoing modifications of structure. The head or mouth end of the animal was more subject to chemical stimulation, and the adaptation of the tactile organs to this particular form of stimulation resulted in the development of the senses of taste and smell. To consider taste as one of the lower senses, in the sense of being least highly developed and the earliest to appear, is justified from this survey of the evolution of the taste sense, if from no other point of view.

CHAPTER XI

Gustatory Imagination and Memory

The Nature and Frequency of Mental Images

It is a familiar fact that in one way or another and in different degrees to different individuals it is possible to have sensory experiences without the actual presence of their accustomed stimuli. Thus, many people can recall "in their mind's eye" the colors of objects, their shape and structure, when they are no longer in the presence of the object thought of. Or, "in their mind's ear," they can hear the blare of a trumpet, the voice of a friend, the hissing of steam, when no corresponding stimulus is present to the ear. Similarly, "in imagination" many can experience the tactual feel of velvet, the odor of onions, the warmth of sunshine, the ache of a tooth, the nausea of seasickness.

"Thus, I can call up in my mind's eye, more or less vividly, my boyhood home, and seem to see, though more obscurely than if I were present on the spot, the house and barn, the grape arbor, the

garden, even my little bookcase in the library. I can smell the honey in the bee boxes, and can hear the general hum and stir of the hive. I can do this because I can call up images of these past experiences. Or, by putting together the images of wheels, sails, birds, and ropes which I have actually seen I can create in my mind's eye an aeroplane of a pattern which has never yet been constructed." This constructive performance would constitute "imagination" as distinguished from mere "imagery."

These images of imagination are not to be confused with the after sensations which we have already described. They may be experienced days, or even years, after the first application of the original stimulus. Nevertheless, these "mental images," or "centrally excited sensations," are described as essentially sensory in character, —they have the attributes of all sensory experiences, such as intensity, extensity, duration, clearness, locality, quality, and modality. In fact, observers have been found for whom these mental images were so realistically sensory that actual negative after sensations, in the case of visual images, have been reported as following upon them.

In the case of many individuals, these experiences of objects in their absence are relatively rare and obscure, and in some cases, indeed, are

so obscure as to lead the individual to deny the existence of such experiences. In still other cases the centrally excited sensations, the mental images, are experienced in their vivid and, apparently, immediately sensory form only under special conditions, as in dreams, hallucinations, drowsiness, or fatigue, or under the influence of special drugs. It has appeared from the study of mental images that, in so far as they are present, they are not equally reported in the different modes of sensation. Visual images in some cases, auditory images in other cases, and motor images in still others, have seemed to be so specially frequent, vivid, or easily aroused that at one time it was customary to classify individuals on the basis of their images as visuelles, audiles, motiles, and efforts have even been made to adapt a method of teaching to the presumed "imagery type" of the student. In the present connection our interest is only in inquiring whether and in what degree "images of taste" are present.

Mental Images of Taste

Is there a "gustatory" or taste imagination as well as a visual or an auditory imagination? It should, of course, be borne in mind that tastes may be "thought of," "referred to," or "indicated" without there actually being taste qual-

ities present in experience. Thus, I may refer to the "saltiness of the pork" and discuss it in detail without having in consciousness the sensory tang and quality of "salt." The saltiness may be "represented" in my thinking in this case, not by a taste quality at all, but by the word which stands for such a quality, or even by a visual picture of a white granular substance, or an elongated strip of meat. Only if the immediate and unanalyzable experience of sensory "salt" is present is there evidence, in this case, of an "image of taste."

Obviously, we must mainly rely in such cases on the testimony of the observer, although there have been investigations made of a more objective sort, in which it is shown that the reported "images" are so similar in character to actual sense experiences that the observer, under appropriate conditions, cannot distinguish between the two.

If we turn to the results of introspection or individual testimony, we find that if taste images exist at all they are at least reported as very much less frequent and vivid than are images from other senses. Thus, one observer, who in the course of two years' observation of his own experience recorded 2,500 "images," classified these as follows:

Vision	57%
Hearing	20%
Smell	6%
Taste	6%
Touch	4%
Movement	3%
Temperature	2%
Organic	1%
Emotional	1%

Much the same state of affairs is revealed if one attempts, when certain objects are named, to record the imagery which the name evokes. In response to the word "tornado" some individuals at once report visual appearances of falling houses and waving trees, while others report auditory experiences of crashing buildings and rushing wind. Within a few moments most observers report the appearance of images from various senses, though some of them are more vivid, more prompt, or more enduring than others. In the case of taste, however, it is rare that images are reported as either vivid, prompt, or lasting. Usually when such an image is reported at all it is described as lagging behind the images of other modes, appearing to be dragged in or reënforced by them, and to be transient, weak, and fluctuating. It seems, also, that, although images of taste are not easily aroused directly by words, their appearance is facilitated if a visual image or impression is present with them. Consequently, when the poet or the advertising writer desires to provoke imagined tastes

in his readers he often attempts to arouse them more effectively by presenting suggestive pictures of scenes associated with the object, or a tempting array of the articles themselves in an agreeable setting.

Taste in Dreams and in Hallucinations

Reports of the sensory components of dream experiences show taste to be an inconspicuous factor in dream life. The following table shows the results obtained by two independent investigators when dreams of various individuals were analyzed into the sensory elements reported:

Sensory Mode	Percentage of Occurrences 381 Dreams	300 Dreams
Vision	84.5%	67%
Hearing	67.7%	26%
Touch	10.8%	8%
Smell	6.9%	1%
Taste	6.3%	1%

Records of the hallucinations of sane and insane people also show taste to play a relatively minor rôle, so far, at least, as frequency of report is concerned. In both cases visual, auditory, tactile, and olfactory hallucinations seem to be more common experiences. "Subjective tastes," or tastes which do not appear to be caused by the action of any substance in the mouth, are, however, by no means unknown, although in most cases it is apparent that these tastes come from some unsuspected irritation of the taste organs by actual agents. Substances circulating in the

blood may often be seen to be responsible for these "subjective tastes." Thus, in diabetes the excess of sugar in the blood may give rise to a persistent sweet taste, and in case of jaundice biliary products often produce sensations of bitter. Various drugs, when present in the blood stream, also provoke well-known effects in taste, and it is quite probable that the taste hallucinations associated with nervous and mental disorder have their origin in some abnormal irritation of the nerves or brain centers involved in taste. Distilled water, which is presumably as tasteless a substance as could be found, is reported as tasteless by only about 50 per cent of observers. About 25 per cent report it as having a bitter taste, while certain cases are found in which it tastes sweet, or salt, or sour, or as having some unknown taste. As the result of careful study of these facts, Brown suggests that "we may perhaps infer that the 'taste' of water is not, after all, a taste quality, but is due rather to the presence or absence of some tactual characteristic; the absence, perhaps, of the 'bite' which is associated with sweet, salt, and sour alike." It is also possible that mechanical stimulation of the taste organs can produce true taste qualities, just as mechanical stimulation of the retina produces spots of light and the tapping of a "warm spot" may produce a faint sensation of warmth.

CHAPTER XII

Unusual and Abnormal Taste Experiences

Gustatory Hallucinations and Auræ

Disorders of taste are for the most part neither as varied nor as bizarre as the abnormal conditions of the more complex senses. Illusions of taste, hallucinations, and subjective tastes we have already referred to as frequently found. But of them little can be said, except that they occur, and that they present very little of psychological interest. The appearance of these subjective tastes may in some cases be due merely to the fact that "a taste sensation easily associates itself with certain muscular sensations. Thus, pressure on the base of the tongue provokes the movements of vomiting. With this muscular sensation may be associated a sensation of bitter, which accompanies violent nausea." In ways similar to this some observers would explain the reports of others who find taste sensations to be produced by mechanical stimulation of papillæ. Most observers do not get such results, and it may be that these sensations when they are reported are of the associated variety.

In the case of certain abnormal nervous conditions, however, these features may assume rather striking proportions. Thus, in the "auræ," or preliminary symptoms preceding an epileptic attack, the patient often experiences unpleasant bitter or metallic tastes, and distressing feelings of numbness of tongue, etc. These sensory manifestations are, however, by no means as elaborate as are the "auræ" of some of the other senses, notably hearing and vision.

Partial and Complete Ageusia

Conditions of partial or complete *ageusia,* or loss of taste, are well known. Such conditions may result from the local application of various drugs to the end organs, the paralyzing effect of drugs on the nerve trunks, injury to, or operations on, these nerves, or damage through injury, disintegration, or removal of special brain areas.

Taste Hallucinations of the Insane

In the case of the mentally deranged taste hallucinations are usually disagreeable, and they are often rationalized into a fabric of delusions, —foul gases are said to be blown upon them, poisons are being placed in their food. Such patients behave in realistic manner, making various defensive reactions, such as stuffing the nostrils with paper or cloth, spitting, and refusing

food. In some cases these hallucinations of the insane obviously originate from local inflammation in the peripheral tissues, or from glandular disturbances, and, hence, do not in themselves constitute important pathological symptoms. In some cases, however, such hallucinations arise quite independently of such acute local conditions of irritation, as in chronic psychic disorders or dementias. Under such circumstances they have greater significance, as they point to more deep-seated mental and nervous disturbance. Just as in normal life taste and smell are very closely associated with each other, so, in these cases of insane hallucinations, disorders of taste sensation are likely to involve olfactory irregularities as well.

Synæsthesias of Taste

An interesting though apparently somewhat rare phenomenon in the field of sensation is what is known as "synæsthesia." By this is meant cases in which a given sense quality arouses, or is intimately associated with, qualities belonging to other sensory modes. Thus, in the case of vision and hearing, some individuals perceive the different vowel sounds, or the sound of musical instruments, as having color. One such person reports that to him all the consonant sounds seem to be very dark purple, while among the vowel

sounds " a " seems yellow, " e " is pale emerald, and " u " is light dove color.

Taste, far from being an exception in this case, is one of the senses in connection with which " synæsthesias " must often occur. Salt, for instance, is described by one observer as dull red, bitter as brownish, sweet as clear bright red, and sour as green or greenish-blue. To another observer the taste of meats seems red or brown, the taste of Graham bread is rich red in color, while all ice creams (except chocolate and coffee) taste blue. To still another reporter the sound of the word " intelligence " tastes like fresh sliced tomatoes, while the sound of the word " interest " tastes like stewed tomatoes. There has been much speculation as to the probable meaning and mechanism of these synæsthetic experiences. Investigation seems to show that the particular combinations are by no means universal, even among those who report such observations,—they seem to be individual and personal in their nature and presumably in their origin.

It seems quite probable that in the main these synæsthesias represent uncritical confusion of sensory qualities with other sensory qualities, or with the affective qualities, the feelings, which accompany them. Thus, we often hear such phrases as " bright taste," " heavy taste," " dark brown taste," " green taste," " soft taste," " hard

taste," "smooth taste," etc. It is clear in most of these cases that either a touch component is included in the total taste experience (as in "smooth taste," "soft taste," "hard taste"), or that kinæsthetic (muscular) factors are so included (as in "heavy taste"), or that the phrase is more or less designedly an analogy, or other figure of speech (as in "sharp taste," "bright taste," "clear taste"). The basis of such analogies is sometimes rather easily discerned, and often is seen to be the "feeling tone" which the sensation arouses,—the effect or "affect" which it produces. Thus, a heavy weight retards, inhibits, and overpowers us. Some tastes have this same overpowering affective tone, and may be intelligibly described as "heavy." A clear, bright day gives us recognizable feelings of pleasantness, relief, and gives to objects a distinctness of contour. Some tastes, being well defined, definitely localized, and highly agreeable and soothing, may, then, be intelligibly described as being "clear," "bright," or "pointed." These illustrations represent, to be sure, only simple forms of such synæsthesias. But even the resemblance of the sound of "intelligence" to the taste of fresh sliced tomatoes is by no means incomprehensible when we reflect that "freshness" means "alertness," "sliced" suggests sharpness of edge, while tomatoes thus prepared are usually

mature and ripe. For are not alertness, keenness, and maturity the very marks of intelligence, just as "dullness" and "greenness," also sense qualities, are expressive of its absence? In somewhat the same way we commonly speak of "sweet odors," "sweet sounds of music," or even sweet visual experiences, as in "a sweet face."

A few individual cases of taste synæsthesia have been studied in some detail. Such individuals are often shown to have a defective sense of taste and to rely largely, in their recognition of taste, on touch accompaniments, affective characteristics, and such "color" experiences as the various tastes are said to induce.

Perversions of Taste

Under certain unusual organic conditions, and also still more commonly in the case of degenerate and neurotic individuals, various perversions of taste occur. These perversions do not seem to be exclusively gustatory in character, since they involve more general factors, such as appetite, craving, and emotional disturbance. The name *parorexia* is sometimes given to these perversions of taste and appetite. One of the subforms, known as *malacia,* takes the form of an urgent desire for hot spices, or for sour and acid foods, such as pickles. What is known as

"salt hunger" is a very similar condition, especially often found among the lower animals. Another form of such perversion, known as *pica,* shows itself in the desire to eat such substances as clay, chalk, and similar gritty or earthy substances. Especially often among children and among certain primitive peoples the chewing of these substances often seems to give a satisfaction quite unfamiliar to the majority of mankind. Little is known about such perversions beyond the fact that they have often been reported.

Under certain conditions of mental degeneracy and nervous disorder perversions sometimes arise which have been classed under the term *allotriophagia.* This perversion takes the form of eating with apparent relish various kinds of filth which are commonly offensive and disgusting. In these cases it is quite possible that there is no genuine taste disorder. Many, if, indeed, not most, of our revulsions against substances known as filth arise on the basis of associated circumstances, rather than on the simple basis of their taste qualities. The falling away, or deterioration, of these associative and æsthetic controls in the case of the demented and degenerate, and their absence in the case of the feeble-minded and imbecile, may easily lead to reactions which suggest but do not necessarily involve genuine taste disorder.

CHAPTER XIII

Food and Flavor

The Biological Rôle of Taste

In considering the function of the sense of taste it is common to dismiss the topic in a summary manner by pointing out the fact, that in its original primitive conditions, at least, this sense enables the organism to discriminate between wholesome and deleterious food. This function is, of course, not to be neglected, especially if due credit be given to the rôle played by smell in the same service. It is however true that, although the indications of taste and smell may be, for lower forms of animal life, fairly trustworthy guides in the selection of edible substances, such criteria as taste and odor can by no means be relied on by human beings. In a general way it is, of course, true that wholesome substances possess taste qualities which are agreeable and enjoyable, while foul, decaying and poisonous substances are often characterized by tastes and odors that arouse in us disgust and revulsion.

But in the complex lives of human beings, at least, this sort of natural adaptation is far from adequate to constitute a dietetic guide. Not only is it true that many substances accessible to human beings are injurious and unwholesome, in spite of their agreeable taste; it is equally true that many substances that are initially distasteful may be either nourishing or remedial. Human beings find it necessary to supplement, or even to supplant, the "beneficent guardianship" of taste by the introduction of various other sources of information and criteria of selection.

We do not find, however, that the sense of taste shows any evidence of deterioration as the result of such loss of function. Probably never before in the history of our race has there been such diligence and zeal in ministering to the demands and satisfactions of our appetite. In the preparation, marketing, and serving of food the appeal through tastefulness and flavor stands second only to that through purity and cleanliness. The situation is neatly stated by Jane Addams in the following words: "Perhaps the neighborhood estimate (of their New England kitchen) was summed up by the woman who frankly confessed that the food was certainly nutritious, but that she didn't like to eat what was nutritious; that she liked to eat 'what she'd ruther.'"

It is clear at once that the satisfactions of taste

are pursued, either secretly or openly, for their own sake, and often in obvious disregard of their dietetic consequences. Shall we dismiss this pursuit as only an instance of the search for pleasure in its own right or wrong, or is there to be discerned a further function of taste experiences quite aside from their guidance to eating, their warning of danger, and their immediate sensory pleasure?

Taste and Digestion

Recent studies of the rôle of taste in the economy of the organism show very decidedly that such an additional function, and a very important one, must be recognized. These investigations have revealed the fact that the pleasurable taste of food (along with its agreeable odor and appearance) is responsible for the initiation of the first stages of the process of digestion. Further, they have shown that disagreeable tastes and odors (along with pain, fear, and other emotional excitement) may effectually retard or even completely inhibit these very important processes. Not only does the mouth "water" at the smell, or sight, or thought, of delicious morsels, but the stomach itself responds, in an anticipatory fashion, to the taste of agreeable substances placed in the mouth. That "good digestion waits on ap-

petite" is a physiological fact, as well as an ancient proverb.

In the middle of the last century two observers in Leipsic reported the pouring out of gastric juice at the mere sight or smell of a favorite food in the case of "a hungry dog which had a fistulous opening through the body wall into the stomach." More recently it has been experimentally shown that similar flow of gastric juice follows upon the tasting of agreeable food, even if the food itself is not allowed to reach the stomach. So relevant are these findings to the point we are now considering that the following summary, by Cannon, of the work of Pavlow may well be quoted in detail:

Experimental Evidences

"The feelings or affective states favorable to the digestive functions have been studied fruitfully by Pavlow, of Petrograd, through ingenious experiments on dogs. By the use of careful surgical methods he was able to make a side pouch of a part of the stomach, the cavity of which was wholly separate from the main cavity in which the food was received. This pouch was supplied in a normal manner with nerves and blood vessels, and, as it opened to the surface of the body, the amount and character of the gastric juice secreted

by it under various conditions could be accurately determined. Secretion by that part of the stomach wall which was included in the pouch was representative of the secreting activities of the entire stomach. The arrangement was particularly advantageous in providing the gastric juice unmixed with food. In some of the animals thus operated upon an opening was also made in the esophagus, so that when the food was swallowed it did not pass to the stomach, but dropped out on the way. All the pleasures of eating were thus experienced, and there was no necessity of stopping because of a sense of fullness. This process was called 'sham feeding.' The well-being of these animals was carefully attended to; they lived the normal life of dogs, and in the course of months and years became the pets of the laboratory.

Pavlow showed that the chewing and swallowing of food which the dogs relished resulted, after a delay of about five minutes, in a flow of natural gastric juice from the side pouch of the stomach —a flow which persisted as long as the dog chewed and swallowed the food and continued for some time after eating ceased. Evidently the presence of food in the stomach is not a prime condition for gastric secretions, and, since the flow occurred only when the dogs had an appetite and the material presented to them was agree-

able, the conclusion was justified that this was a true psychic secretion."

In several cases necessary operations on human beings have permitted of observations similar to these experiments on dogs. Thus, Richet, who had opportunity to observe such a case, "reported that whenever the girl chewed or tasted a highly sapid substance, such as sugar or lemon juice, while the stomach was empty, there flowed from the fistula a considerable quantity of gastric juice." Another observer, Hornborg, "found that when the little boy whom he studied chewed agreeable food a more or less active secretion of gastric juice invariably started, whereas the chewing of an indifferent substance, as gutta-percha, was followed by no secretion."

Carlson has reported numerous similar observations on an adult. In the case of this man the sight, smell, or thought of food, even when he was hungry, was inadequate to cause the gastric juice to flow. Moreover, "the mere act of chewing indifferent substances, and the stimulation of the nerve endings in the mouth by substances other than those related to food," caused no secretion. But a few minutes after the taste organs were stimulated by edible substances it was seen that not only did the flow of gastric juice begin, but the "hunger contractions" of the stomach were inhibited. Further, the secretion of

gastric juice in this patient was clearly seen to vary with the palatability of the food. The chewing of bread and butter yielded a smaller flow than did the mastication of meat, and the flow was always greatest during the chewing of desserts, or on occasions when the food was said to be "unusually fine." Oranges, of which the patient was especially fond, produced a greater flow than did pies, puddings, and other fruits. Carlson, in reporting these observations, says: "There is no question but that the mastication of a palatable dessert at the end of a meal serves to augment and prolong the appetite secretion of the gastric juice."

In referring to such cases Cannon has concluded: "All these observations clearly demonstrate that the normal flow of the first digestive fluids, the saliva and the gastric juice, is favored by the pleasurable feelings which accompany the taste and smell of food during mastication, or which are roused in anticipation of eating when choice morsels are seen or smelled. These facts are of fundamental importance in the serving of food, especially when, through illness, the appetite is fickle. The degree of daintiness with which nourishment is served, the little attentions to æsthetic details—the arrangement of the dishes, the small portions of food, the flower beside the plate—all may help to render food pleasing to

the eye and savory to the nostrils, and may be the deciding factors in determining whether the restoration of strength is to begin or not."

The Function of Taste in the Organic Economy

The preliminary nature of these anticipatory secretions of the digestive juices is by no means an adequate measure of their ultimate importance. Studies of the mechanism of digestion show that each stage, as it occurs, either directly or indirectly, through its product, affords the appropriate stimulus which evokes the following stage. Thus, continued flow of gastric juice is provided for by the action of the preliminary flow or its products on the walls of the stomach; and other juices, such as the bile and the pancreatic, are in turn released by the action of this continued flow.

The pleasurable sensations of taste are thus the initial stimulus to the whole series of digestive processes. Even in the absence of hunger these sensations seem potent to initiate the digestive mechanism. Among the most interesting of recent physiological studies are those showing the very great sensitivity of the important organic mechanisms, especially those of secretion, to such experiences as shock, worry, fear, anger, grief, excitement, and pain. All these factors tend to retard the activity of the digestive system, while

they may also be seen to reënforce the activity of other mechanisms. As opposed to the effect of these factors, pleasurable experiences connected with food serve not only to guide the organism in its choice, but play an important part in its effective appropriation and assimilation, through their action in setting the digestive mechanisms in action, and in guaranteeing the continuation of this action after the completion of the act of eating.

Music and dance, jest and general merriment, genial conversation and cordial friendship, prosperity and individual success, fragrance, color, bodily ease, and a clear conscience—these and all the other joys of life play their part in promoting the bodily welfare of the organism. Conspicuous and potent among these favoring influences are the sensations of taste and the strongly toned feelings with which they are so closely associated —"the satisfactions of the palate." Even the various "bitters" which are so commonly used as "appetizers" seem to owe such efficacy as they may possess to the influence of their taste on the preliminary flow of "appetite gastric." Carlson has shown that these bitters, introduced directly into the stomach in medicinal doses, have no influence on the hunger mechanisms. In larger doses their effect is inhibition of hunger. Acting in the mouth, they also retard the hunger con-

tractions of the stomach in proportion to their intensity as taste stimuli. In so far, then, as "bitters" are "appetizing," it is by virtue of their taste qualities, rather than their medicinal properties, and the act of swallowing them would seem to be superfluous.

CHAPTER XIV

The Æsthetic Value of Taste

The Higher and Lower Senses

When people are asked to state which are the higher and which the lower senses they feel no hesitation in deciding. When asked to arrange the various senses in an order of merit on this basis they are able to do so promptly. Moreover, their various arrangements agree very closely with each other. Vision commonly stands at the top of the series; then hearing; touch and smell are given third and fourth places about equally often; taste is likely to be next; and finally temperature, sensations of movement, and the more general organic sensations. When asked to state what meaning they give to the term "higher" in making this arrangement there is more disagreement in the nature of the replies. Occasionally an individual asserts that by "higher" he means more elaborate, complicated, —"highly" differentiated. A few individuals mean by "higher" more useful, indispensable,— "higher" in value. But by far the larger num-

ber of individuals mean neither the one nor the other of these two notions, but have in mind some characteristic which is not immediately related either to structural complexity, genetic antiquity, nor practical utility,—a characteristic which can only be described as ethical or æsthetic.

Evidence of a cleavage of the senses on an ethical basis is abundant. Quotations from Burton's "Anatomy of Melancholy" may serve as representative of statements that can easily be found in the writings of all centuries, from the Socratic period, through the reflections of the schoolmen, down to the modern textbooks of psychology. Says Burton:

"Of these five senses sight is held to be most precious and the best. . . . Hearing is a most excellent outward sense. . . . Taste is a necessary sense. . . . Touch, the last and most ignoble of the senses, yet of as great necessity as the others, and of as much pleasure."

Contemporary phraseology and convention are just as eloquent in the matter. There is common agreement that some of the senses, in their exercise or consequences, are ennobling, dignified, pure, and worthy; others, either in their exercise or consequences, are felt to be degrading, debasing, vile, and iniquitous. An individual who revels in impressions of sight and sound, and indulges to the utmost the raptures afforded by the

tones, melodies, concords, the colors and their harmonies, and the elements of form, design, and arrangement, we are likely to find classified by his associates as "sensitive," "temperamental," "artistic." But one who revels to the same or even much less degree in the unholy impressions of contact, temperature, smell, and taste is held to be "sensuous" rather than "sensitive," "gluttonous" rather than "temperamental," and "vicious" rather than "artistic." The former pleasures minister to a "divine fire," the latter only to "lust" and "appetite."

Similarly, we esteem in quite distinctive manner the workman whose craft consists in the preparation and arrangement of sights and sounds in pleasing elements, orders, and compositions. He is held to have "acquired merit," however unsuccessful his labors, and receives warm social approbation. He is an "artist." But the workman whose craft consists in the preparation and presentation of acceptable sensations of taste, smell, touch, and temperature, what of him? He is neither held to have "acquired merit" nor to deserve any enviable amount of social recognition. He is only a "cook," a "chef," or, at the most, a "chemist" or a "dietitian." Only in the comic supplements is he ever an "artist." Painting, for instance, is held to be an "art"; but cooking is only a "serv-

ice." The one is rewarded by distinction and eminence, the other, when rewarded at all, by wages.

In the field of æsthetics the distinction between the "higher" and the "lower" senses is no less clear. Museums and galleries we have in abundance in which are preserved and displayed the treasures of light and shade, color and form, line and arrangement. Private and public funds are appropriated in order that these impressions may have the widest possible circulation. Visitors and classes throng the corridors of these storehouses; teachers and schools flourish on the profits derived from the communication and publication of the principles concerned in their manufacture; statues are erected to the most deserving craftsmen; and earnest apprentices starve in foreign garrets in order that their handicraft may in time adorn these walls. Much the same thing is true of pleasing arrangements of sound impressions. All possible pains are taken to record the scheme and plan of their production, and the heartiest welcome is accorded any device, instrument, or organization which will facilitate their being stored up and poured out again for the delectation of remote or future audiences.

But to what museum or gallery shall one go who longs to experience the glorious array of pleasing contacts, textures and pressures, odors,

tastes, and temperatures? Where shall one find stored up representatives of the most satisfying and thrilling touch impressions that experience has ever yielded, the whole gamut of delectable odors, with all the offensive ones left out; all the aromas and savors and flavors in which the gustatory and olfactory world is so rich? And all the organic thrills, the kinæsthetic whirls and starts, and the delicious dizzinesses of static experiences? Coney Island and its brood are the only institutions that even pretend to minister to those whose nature yearns for these satisfactions, and Coney Island is supported neither by philanthropic endowment nor by public appropriations. It is even said that its joys are thought to be "vulgar" among certain classes of people, whose passions run mainly toward sights and sounds.

There can be no doubt about it. Certain of the senses are more æsthetic than others, if by this we mean that special arts have been built up which busy themselves with the materials afforded by them. Certain of the senses, again, are unæsthetic, in the sense that the materials afforded by them have not yielded to that sort of structural manipulation which constitutes the procedure of one of the "fine arts." And, furthermore, such manipulation as they do submit to is not only not considered "fine," but is designated by the negative term "unæsthetic"; the materials them-

selves, as well as those who busy themselves with them, are quite likely to be esteemed "coarse" and "nasty."

Bounty of Nature and Ecclesiastical Censorship

One may well inquire into the reasons for such a curious state of affairs. Does it merely signify that agreeable sights and sounds are so rare in nature that special social encouragement has come to be given for their production, while pleasing contacts, pressures, tastes, smells, etc., are so abundantly provided in the natural course of experience that no such sanction is called for? Even if this were true, does it follow that the sanction of the one group need necessarily involve the taboo of the other? Does it perhaps merely indicate that early in the history of art the Church and its leaders learned that the original tendency of men and women to indulge themselves in the voluptuous impressions of certain of the senses was so strong that the immediate joys of earth promised to outweigh the promised blessings of heaven? Such a discovery might well have resulted in an authoritative denunciation of these types of experience and in an artificial exaltation of the tamer and milder senses, whose objects could be perceived at a remote distance and by many observers, and could be, therefore, more minutely scrutinized by the ecclesiastic censors.

Or does it perhaps mean that some of these sense impressions from their very nature are either unsuitable as materials for that sort of manipulation and craftsmanship which we call artistic, or, from their very nature or consequences, are inimical to and destructive of those endeavors which we have come, on other grounds, to conceive to be the most worthy and valuable tendencies of men and women? The bounty of nature and the ecclesiastical censorship we may dismiss from the present consideration, however worthy they may be of reflection, and confine our present inquiry to the question of whether or not the impressions afforded by some of the senses, such as taste, for example, are, by their very nature, inadequate as raw materials of æsthetic manipulation and artistic creation.

The Psychophysical Attributes

It may be well to begin our inquiry with a consideration of certain of the technical psychological characteristics and properties of the different senses, properties which can be measured and expressed in quantitative terms. We may then observe whether their order, when arranged on these bases, shows any correspondence to their order in the scale of æsthetic value, and where, in such a scale, the sense of taste belongs. The following table brings together the facts concern-

Order of Æsthetic Value	Number of Discriminable Qualities	Sharpness of Discrimination	Average Speed of Reaction	Average Duration of a Sensation, Degree of Inertia
Sight	About 40,000	Difference of 1%	.189 sec.	About .030 sec.
Hearing	" 15,000	" " 33%	.146 sec.	" .002 "
Smell	Nine classes, each with hundreds of qualities	" " 25%	Difficult to determine	Very long and difficult to determine
Touch	Three or four classes with qualities not easily determined	" " 33%	.149 sec.	.001 to .002 sec.
Taste	Four classes with number of qualities not determined	Doubtful	.300 sec. to 1.000 sec.	Very long and difficult to determine
Kinæsthetic (Movement, Strain, etc.)	Four or five classes with number of degrees not determined	Difference of about 5%	Difficult to determine	Undetermined
Temperature	Two classes. degrees not determined	Variable and difficult to determine	.150 sec. to .180 sec.	Difficult to determine
Organic	About six classes	Unknown	Unknown	Unknown

ing four of these characteristics. In the first column the senses are arranged in the commonly accepted order of æsthetic value, and the degree of correspondence can be easily made out by comparing this column with those in which the various other properties are indicated.

It requires only a glance at this table to reveal the fact that we possess much more definite knowledge about sight and hearing in these respects than we do about the other modes of sensation. In the case of these two senses, the four characteristics indicated in the table can be stated with considerable precision and certainty. But in the case of the other senses, and of taste in particular, only broad and vague statements can be made, for the most part. Even the number of discriminable qualities which these senses afford is unknown, and statements concerning the other properties are mainly confessions of difficulty or ignorance. It is difficult to judge to what degree this state of affairs is due simply to the greater attention that has been given to sight and hearing in precise psychological investigation, and to what degree it is due to difficulties inherent in the nature of the sense impressions afforded by the other modes. Nevertheless, it is apparent that no one of the special characteristics indicated in the table can be held responsible for the sharp cleavage commonly made between the worthy and the

ignoble senses. Consideration of the characteristics in detail shows that we must look elsewhere for the reasons why the lower senses are unæsthetic, and even, perhaps, for the reasons why they are lower.

With respect to number of discriminable qualities, for instance, sight and hearing, with their many thousand distinguishable degrees of impression, might seem to afford such an abundance of raw material that this alone would explain why the principal fine arts have come to be based on these senses. But it must be pointed out that this enumeration of qualities has reference only to the definitely identifiable, classifiable, and controllable degrees of impression. The mere fact that odors can be classified under only nine headings, to which general terms can be given, does not at all mean that there are but nine distinguishable smells. Almost every different object in the world has its own characteristic odor. We have not developed abstract names for these odors, to be sure. We are usually content to designate the odor by the name of the object with which it is associated. And when one bears in mind the multitudinous variations of these odors, their different intensities, mixtures, and modifications, one is inclined to believe that it is only the infinite variety of smell experiences that prevents our enumerating, classifying, and designating them. And what

has just been said of smell is equally true of touch, taste, and organic sensations. It is also true that the separate lower senses are seldom stimulated independently,—thus taste is always accompanied by smell, touch, temperature, etc. May it perhaps be true that the very fact that these impressions cannot be estimated, isolated, and reproduced at will has something to do with their inferior æsthetic value? However this may be, it is clear that the mere variety of impressions afforded is not the criterion of which we are in search.

One might be tempted to suppose that the sharpness of discrimination of the various senses, the keenness with which differences in the strength and intensity of impressions can be detected, might be an important factor in determining their availability for æsthetic manipulation. The figures given in the table under this heading indicate the proportion that must be added to a stimulus in order to make it just perceptibly more intense. The temptation is removed at once by a mere inspection of the values. Sight is, to be sure, the most delicate of the senses in this respect, as it is also in number of isolable qualities. But kinæsthetic sensation follows close upon it, while smell stands third in the list, and hearing is no more sensitive than pressure. In the case of taste and the other senses the values are unknown or diffi-

cult to determine, but it is clear that the æsthetic values of the different senses do not depend merely on their various psychophysical constants.

The quickness with which one can react to or perceive impressions from the various senses discloses much the same state of affairs. Basing our comparison on the average reaction times to the most commonly available impressions and intensities in each case, hearing, touch, and temperature are seen to be about equally prompt, while sight stands fourth on the list. With respect to the period of time through which a sensation continues to persist, the so-called "life span" of an impression, only three of the values, those for sight, hearing, and touch, have been determined, and these bear no significant relations to each other. But these times are all very short, and the corresponding modes of sensation stand high in the æsthetic scale. The other values, although not determined, are known to be much longer than these. Is it possible that the sluggishness of these senses and the persistence of impressions once set up through them is so great that the impressions do not submit to the forms, patterns, and structures which constitute artistic treatment? Or may it not be equally true that the fugitive character of impressions from the higher senses is what has made necessary the development of treatment by means of pattern and structure?

The Tendency to Adaptation

Suggested by this question of "life span" of sensations is another characteristic which one might expect to find important,—viz., what we have in an early chapter referred to as the "tendency to adaptation" of the different senses. In the case of odors, temperatures, and contacts, we easily and speedily become adapted to continuous presence of impressions and cease to be aware of their existence. Thus, we soon become adapted to the presence of hats on our heads, the clothes on our backs, the smell of smoke, and even to such extreme temperatures as that of the stoking room. Continuous stimulation of one of these senses so raises the threshold of the sense organ that the original stimulus ceases to be effective. So far as practical and æsthetic purposes are concerned, we are then fatigued to the particular impression. We may be gratified to find that this tendency to adaptation is not nearly so conspicuous in the case of sight. But we will be equally dismayed to learn that the tendency is as prominent in the case of hearing as it is in the so-called lower senses. Moreover, this tendency refers to continued stimulation of the same degree or quality, whereas in æsthetic manipulation the qualities presented are varied from moment to moment and from point to point.

Spatial Attributes of Taste Qualities

On the whole, then, these strictly psychological or psychophysical comparisons are so unsatisfactory that we are compelled to look elsewhere for the criteria of the raw material of æsthetics. Some writers have suggested that the absence of definite and formal spatial attributes and systems is what makes certain of the senses unsuitable for æsthetic treatment. But there are two important objections to this suggestion. One is our earlier question as to the reasons why æsthetic treatment should necessarily consist of arrangement in spatial and temporal series and patterns. Unless some excellent reason to the contrary is given, we are free to assume that this is not a necessity, but merely an incidental result, following from the character of the materials, which, for other reasons, for which we seek, are chosen as the raw materials for æsthetic treatment. The other objection, which is, perhaps, more convincing, is the fact that, whereas touch and kinæsthetic impressions both possess immediate voluminousness and take their place readily in a spatial manifold of position, direction, distance, and form, they do not yield to æsthetic treatment; while sound and taste, one of which easily ranks second and the other of which belongs low down in our æsthetic scale, possess extent in only a very doubtful and

probably analogical manner, and are almost, if not wholly, lacking in those qualities which would enable them to participate in a manifold of position, direction, distance, and form. As for temporal attributes, such as duration and sequence, all impressions possess them, from whatever sense they originate. The idea that the difficulty or impossibility of giving spatial and temporal form to the lower sensations prevents the representation of nature by means of them, and that this is a sufficient reason for regarding them as inferior is anything but adequate.

Immediate Affective Value of Taste

Perhaps the greatest surprise comes when we consider the immediate affective value of impressions from the different senses. Impressions of taste, smell, and contact bear with them or immediately provoke very definite and powerful feelings,—feelings of pleasantness and disagreeableness, excitement and calm, tension and relief. Still more complex emotions than these simple feelings are called up more easily and universally by impressions from these senses than in any other way. Their immediate pleasure tone and their associated emotions may be, and usually are, exceedingly rich and intense. The smell of new-mown hay, coffee, flowers, whiffs of the salt sea breeze, the odors of animals, foods, spices, and

herbs move us to strong emotions. The stroking of fur, the cool of evening, the delicious languor of a sun bath—all these have high and immediate affective value that can hardly be exceeded by any emotions provoked by colors, forms, noises, and tones. In general, those senses that are closely connected with our personal and bodily welfare, as is the case with taste, provoke strong affective reactions and convey to us a strong sense of reality. Those senses which are much less intimately related to our immediate bodily welfare possess much weaker feeling tone and provoke much less emphatic emotional reactions. Disagreeable odors, tastes, and contacts are quite beyond our endurance, but few are the sights and sounds to which we cannot easily reconcile ourselves. Here, then, we have the interesting and perhaps unexpected fact that the sense impressions possess æsthetic value just to the degree that they fail to arouse in us definite and powerful feelings. The inverted arrangement on the basis of æsthetic value gives us precisely the order on the basis of immediate affective value. Santayana's assertion that the small range and variety of pleasure-toned qualities among the lower senses explains their non-æsthetic character, in part, is seen to be not only inadequate, but even a perversion of the facts. Just in that degree to which sense impressions fail to produce in us

immediate pleasures and aversions, fail to provoke us to instinctive emotions of joy and disgust, fail to stir in us moods of irritation and acquiescence,—in just that degree do they declare themselves to be adequate raw materials for the fine arts. If, as we are often told, the primary purpose of art is to please, this must be an entirely unexpected state of affairs, and the low position of taste in the æsthetic scale becomes quite unintelligible.

Development in the Individual and the Race

Perhaps this is as appropriate a place as any in which to point out that the order of the senses, on the basis of their æsthetic value, is approximately that of their philogenetic and ontogenetic development. The simplest and most undifferentiated forms of animal life possess, in more or less rudimentary form, sensitivity to impressions which must resemble closely what we know as contact, pressure, movement, and temperature. Touch, as Aristotle tells us, is the "mother sense." Starting from this form of sensibility as a basis, the other senses develop as we ascend the animal series, by processes of increasing complexity and refinement. Taste and smell, as we know those experiences, were probably the next to differentiate themselves from the vague mass

of tactual and organic sensation, then hearing, and last of all sight. And there is evidence of sequence within a single sense; thus it would appear that brightness vision, sensibility to mere light and shadow, antedated color vision by a considerable interval, and even that sensibilities to the various color impressions developed in some sort of serial order. It is also true that the sense organs upon which fall the stimulations of the physical world are, at the birth of the individual, in very diverse conditions of functional perfection. The nerves which underlie sensations of taste, touch, temperature, and pain operate perfectly at birth. Hearing is defective for one to two weeks after birth, and the mechanism of vision is still more imperfect and commonly remains so for several weeks. From the point of view of the three meanings of the word " higher," the ethical, the æsthetic, and the genetic, the order of the senses is the same. Such close agreement cannot be entirely without significance.

The Imaginative Value of Taste

A further characteristic which correlates closely with the æsthetic arrangement is to be found in the relative ease with which images can be called up and contemplated in the various modes of sensation, in the absence of any physical stimulation, —what we may call the imaginative possibilities of

the different senses. With most people visual and auditory imagery is both more vivid and intense, and more facile and prompt, than is imagery within any of the other sensory modes. We have in another section referred to one observer who recorded his mental images as they occurred or were noticed until 2,500 had been enumerated, and who reports that 57 per cent of them were visual, 29 per cent auditory, leaving only a total of 14 per cent for images from all the other senses. Dreams, which consist mainly of imagery experiences, are commonly visual in character, with hearing a close second, and the other modes hardly represented at all. Hallucinations reported by supposedly normal people are in 90 per cent of the cases either visual or auditory, and the visual are about twice as frequently reported as the auditory. Records of hallucinations among the insane show vision and hearing clearly most prominent, with hearing somewhat more prominent than sight. Can it be that the possibility of recall in the form of imagery, contemplation in the absence of the original stimulus or object, is one of the prime qualifications of sensory impressions that are to serve as æsthetic material? There will probably be no exception taken to such a generalization on the part of anybody. The order on the basis of imaginative value is identical with that on the

basis of æsthetic value, ethical value, and genetic development.

The Non-Social Character of the Lower Senses

It is interesting to note that the higher senses are also the so-called distance receptors; they do not require immediate contact with the stimulus-producing object, whereas the lower senses inform us mainly concerning objects that are in direct or approximate contact with our own body. By virtue of this fact, as has often been remarked, it is possible for many of us to *see* the same object, such as a rainbow, however far apart we may be from each other. And we can all hear the same melody-producing instrument if we place ourselves within a certain fairly large area. But social experience is scarcely possible in the case of contact, taste, smell, temperature. Here the most we can do is to get the experiences in succession, and even this is often impossible. Even when it is possible to get the experiences in this way, by taking turns, we find it difficult to confer over them, since all conference is now on the basis of memory images, and, as we have already seen, we find it difficult, if, indeed, not quite impossible, to call up clear and persistent images of the impressions afforded by these senses.

It is true of some of these senses that in their

enjoyment the stimulus itself is consumed. Whenever this is the case the sense concerned will be found to be one of the so-called lower, unæsthetic senses. Not only is social experience of the enjoyable object impossible, but even the single individual cannot himself get the experience again. Can it be, perhaps, that, as Thorndike remarks, "the pleasures of taste are not called æsthetic because one cannot eat his cake and have it, too"? It begins now to look as though only those sense impressions can become æsthetic vehicles which somehow lead beyond themselves, and beyond the immediate gratification of the individual, and facilitate some sort of social operation, or conference, or participation. In saying this we do not have reference to the doctrine that one often hears emphasized,—viz., that the lower senses, such as taste, are low and unæsthetic because they minister mainly to our personal and physiological needs. Nothing could be farther from the truth. It is not because taste, smell, and touch are mainly concerned in telling us of facts that are of fundamental vital importance to us as individuals that they are low or unæsthetic, but only because they do nothing more than this, —because they cannot become the vehicle of our individual and social conference and communication.

In this connection let me quote an illuminating

comment from Miss Calkins' chapter on "Perception" in her "Introduction to Psychology." As she there writes:

"It thus appears that even perception, the consciousness, as we call it, of outer things, is a consciousness of other selves as sharing our experience, a relatively altruistic, not an exclusively egoistic mode of consciousness. This is the reason why we usually speak of sight and hearing and smell as higher senses—and in the order named—than taste and the dermal sense experiences. Vision is the sense most readily shared by any number of selves: for example, everybody within a very wide area may see the mountain on the horizon or the Milky Way in the evening sky. Next to vision, sounds are the most frequently shared experiences; millions of people hear the same thunder and thousands may share the same concert. Even odors, though shared by fewer people, may be common to very many, whereas tastes and pressures and pains, which require actual bodily contact, and warmth and cold, whose physiological stimulation depends on conditions of the individual body, are far less invariably shared experiences. But the shared experiences are those that are described, discussed, repeated, measured—in other words, those that are creatively reembodied in works of art and in scientific investigations. Vision, therefore, is a higher sense than the others, only in so far as it is more often shared, and hence more often discussed and described, measured and verified. This is the reason why it is a more significant social material of intercourse, art, and science. Pressure and warmth, on the other hand, are less valued, because they are less often actually shared and, therefore, less easily verified and less frequently described."

This, we have said, is an illuminating paragraph. But it is satisfactory only when amplified in certain ways to which we seem to have been led in our preceding discussion. Thus, it cannot be said that the socially shared sense impressions are chosen as the raw material of the fine arts merely because they enable a multiplication of individual pleasures. The dominant passion of the artist is not merely to afford pleasure to the greatest possible number of observers. But so long as art is defined as an attempt to please, that is about all that follows from the social character of the higher senses. As a matter of fact, artists do not seek to please the greatest possible number of observers. They are often contented if a single observer is satisfied. And by satisfied, in this connection, one does not mean pleased. We have already seen that the most pleasing of all sense impressions are those afforded by the lower senses. If the mere production of pleasure is the chief aim of the artist, he would surely have resorted to those materials which in themselves and by their own direct effects facilitated his purpose.

The Unsystematic Relations of Taste Qualities

Another characteristic of those sense materials which enter into art products,—especially vision and hearing,—is the fact that the various experi-

ences constituting the sense manifold exhibit structural and systematic relationships. We do not here refer to the possibility of spatial arrangement and form. This we have already discussed and dismissed as an inadequate criterion. We mean, rather, those facts represented, in the case of vision, by the color pyramid and similar schemes for representing the qualitative relations of visual sensations; and, in the case of sound, by the tonal scale and such graded intensity scales as may be devised. Definite and formulable relations with respect to such facts as fusion, harmony, tonality, and melody; saturation, contrast, complementariness, mixture, etc., may be made out in the cases of vision and hearing. Æsthetic manipulation takes the form of playing upon these relationships. The visual and auditory qualities constitute not merely a manifold, but yield systematic structures. But the sense of taste and the other lower sensation modes tend to constitute a mere unorganized manifold.

Now, it may be at once suggested that we here have the adequate criterion of the æsthetic for which we are searching, and that this is at bottom the reason why it is the visual and auditory experiences that are "described, discussed, repeated, and measured (and) creatively reëmbodied in works of art."

But even this account is, as a matter of fact,

very one-sided and in part, at least, fallacious. We do not know what structural systems would be exhibited by the lower sense experiences if we had only discussed them, measured them, and creatively embodied them to the degree to which we have gone in the case of the higher senses. We cannot be sure, in the present state of our knowledge, to what degree the appearance of superior organization on the part of the higher senses is due to the amount of effort and inquiry we have bestowed upon their examination. All that we really know is that innumerable studies have been made of sight and sound, and that we are able to represent their results in the form of schemes and systems; whereas, comparatively few studies of the intensive type have been made of the various "lower senses," and we are proportionately unable to construct the corresponding schemes and structures. Which is cause and which is effect? Do the lower senses fail to provide the raw materials of æsthetic construction because of their lack of elaborate and systematic organization, or do they owe this very deficiency to the relative neglect they have suffered at the hands of the artist?

The Motive of Æsthetic Products

There is some further reason why the æsthetic sense impressions are those which are genetically

most recent, in imagination the most capable of clear and persistent revival, pertaining mainly to the distance receptors, informing us of objects which may be socially shared, and capable of systematic and organized description. It seems that this reason is simply that the main thing about an æsthetic presentation, arrangement, or composition is, after all, its intellectual content, its "message." The artist desires, above all, to eliminate our own immediate and instinctive reactions to his materials. In so far as he is an artist, he is not satisfied with presenting to us a pleasing array of sense materials. His main concern is in communicating to his observers some situation, some theme, some state of affairs, some meaning, some purely relational fact. Such emotions as are stirred in us he does not wish to come from his mere materials, but from his own manipulation of them, from the form or pattern which he gives them, from the meaning which he thereby conveys to us. The true artist, in other words, is neither a chemist, nor an athlete, nor a technician of any sort whatsoever, but a philosopher.

Stout makes a similar comment when he says: "The distinction between what we call the higher and lower senses rests on this contrast between the intrinsic impressiveness of sensations and their value for perceptual consciousness. . . . The relatively higher senses deserve this

title in proportion as they are more delicately discriminative and more capable of being combined in successive and simultaneous groups and series, while preserving their distinctive differences. On the other hand, each several sensation is proportionately less important through its own intensity and pleasant or painful character. Any direct effect produced by its own intrinsic intensity and affective tone would interfere with its value as a vehicle of meaning—as an indication of something beyond its own existence. Thus, as perceptual consciousness becomes relatively more prominent and important, sensation is more delicately differentiated, more definitely restricted, less intense, and less strongly toned in the way of pleasure and pain."

The comments one is offered in the books on "art,"—eulogies of Raphael's rich color tones, Rembrandt's lights and shadows, Rubens' flesh tints, Meissonier's minute details, Turner's accurate reproduction of ferns and mosses, smoke and fog, and so on, represent a deliberate degradation of the work of the artist to the level of cookery, the manufacture of perfumery, dyestuffs, and the operation of merry-go-rounds. It is crediting the artist with just that result which æsthetic manipulation has always sought not to produce,—the presentation of sense materials, which of their own right awaken strong feeling

tone in the observer. When George Frederick Watts attempted, beyond those before him, to convey meaning through his arrangements of sense impressions he refused to attend minutely to the details of technique, and critics subsequently said of him, "His technique is faulty." Perhaps it was, but that is the sort of comment one passes on an athlete, a ventriloquist, or a juggler. One might just as significantly criticize the literary style of a mathematician or a logician as the technique of an artist. Such criticisms, to be sure, have a legitimate place in life. But the critic of the mathematician's literary style should not delude himself into the belief that he is discussing mathematics, nor the critic of the artist's technique fancy that he is dealing with his art. For the real artist is a philosopher, and that is the reason why the lower senses are unæsthetic.

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